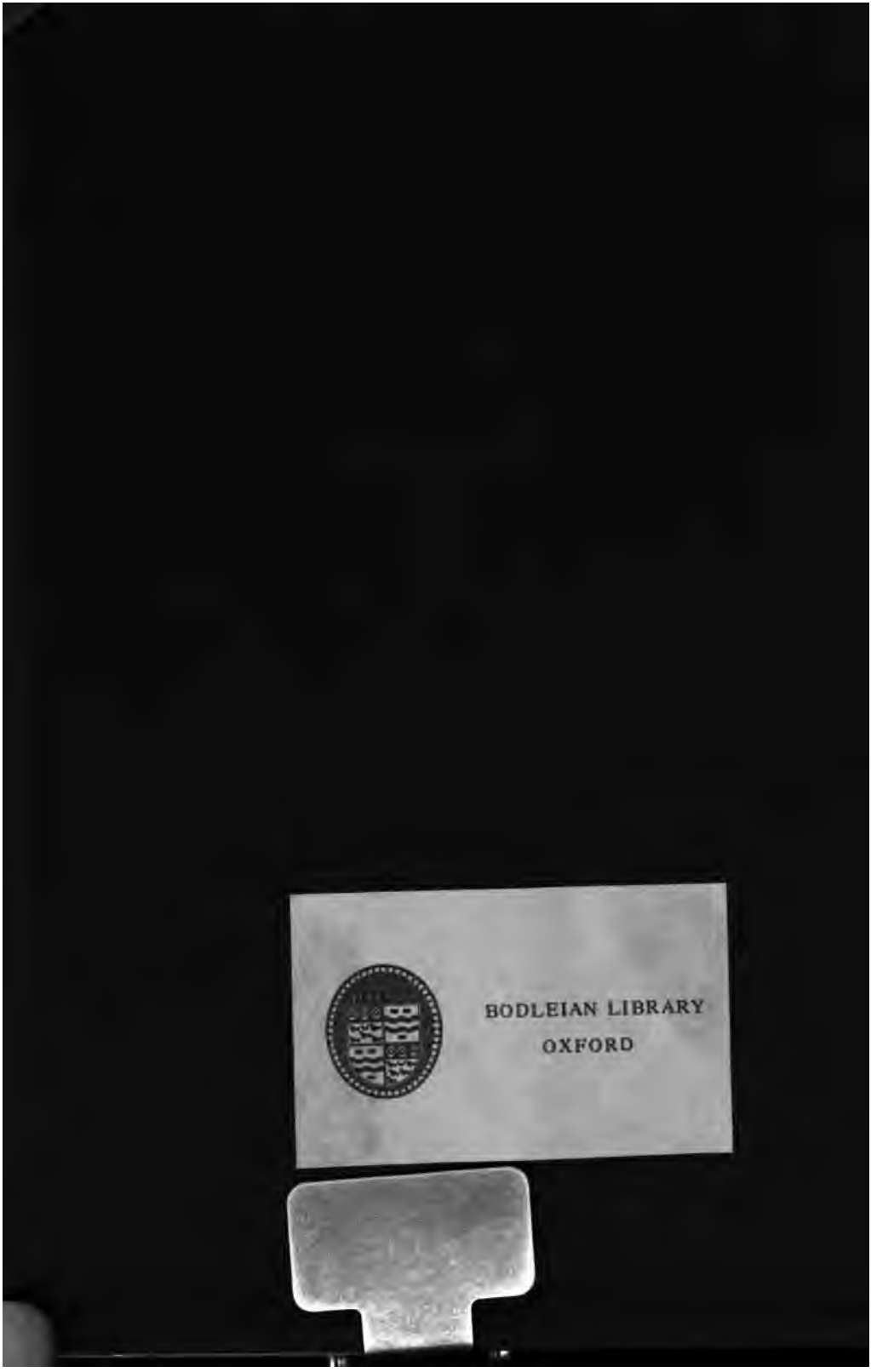
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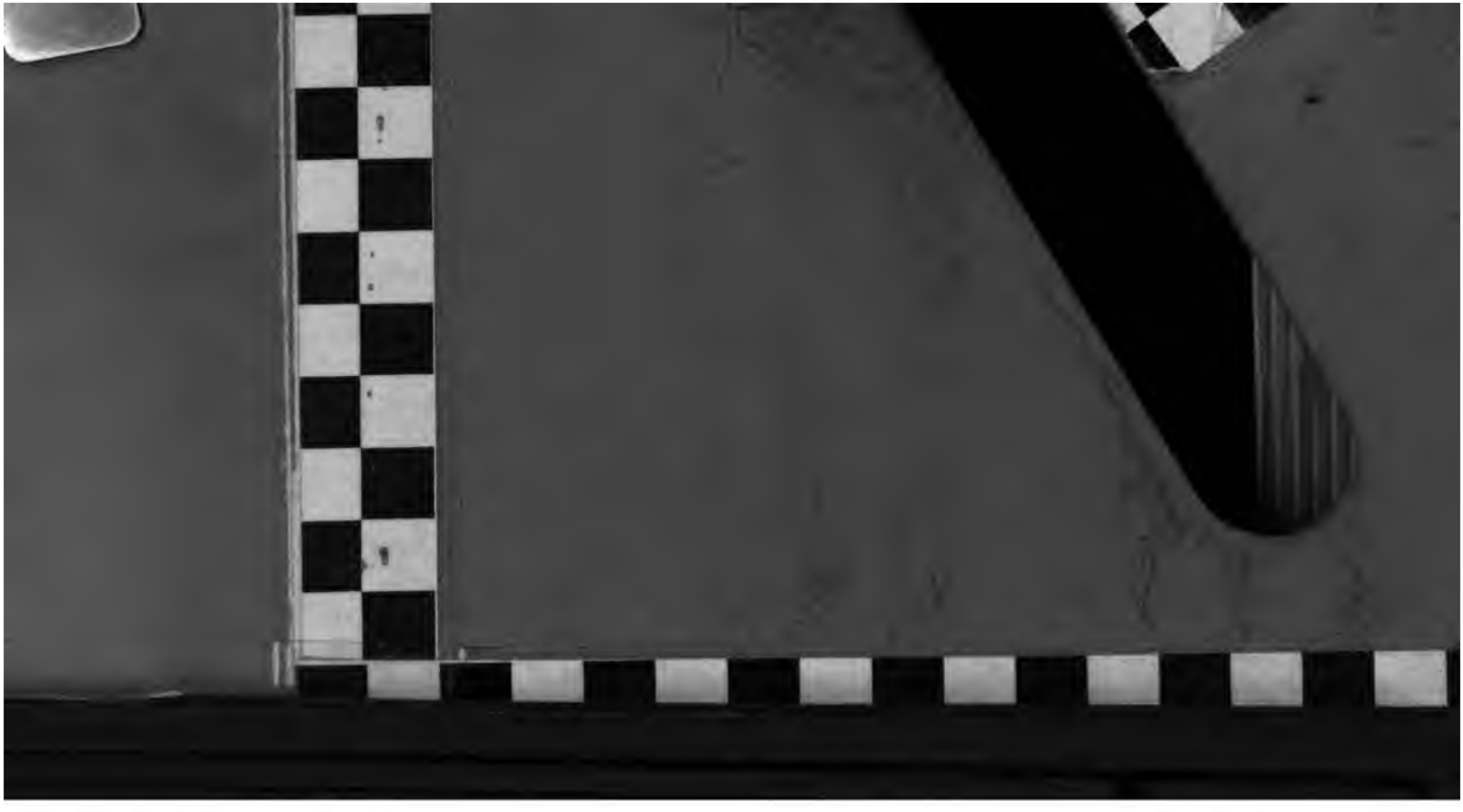

Coal.

aneous Combustion

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OCCURRING IN

L CARGOES,

&c.

OMAS ROWAN.

Authorities Consulted or Referred to.

REPORT OF THE ROYAL COMMISSIONERS APPOINTED TO ENQUIRE INTO THE SPONTANEOUS COMBUSTION OF COAL IN SHIPS. (1876).

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In Preparation, by the same Author.

A TREATISE

ON

VENTILATION,

IN which the Author describes his system of Ventilating the SEWERS OF TOWNS with the disinfection of the Sewer Gas—The Ventilation of House Sewers and Drains, &c.

The Ventilation of Rooms and Buildings. How to insure a constant supply of pure air of uniform temperature, &c.

HOSPITAL VENTILATION.—The Ventilation of the Wards for Small Pox and other Infectious cases—Ventilation of Wards for Consumption and Pulmonary Complaints, &c.

PREFACE.

ATTENTION has never been directed with, perhaps, greater interest than at the present time to the subjects which I have endeavoured to deal with in these pages—

After the Royal Commission of 1875, appointed to enquire into the spontaneous combustion of coal in ships, expectations were formed that, at last, measures would be devised for minimising, at least, the risks which have attended the carriage of coal in ships. How far this has been accomplished will be seen from statistics given at Pages 28 and 34, and also Appendix D.

An examination of the subject now has the great advantage of reviewing the labours and testing the value of the "suggestions" contained in the Report of the Royal Commission, of 1875, by the results which have followed, and thus ascertaining how far those "suggestions" have produced any practical benefit, and where they have failed.

I have also in Chapter IV. and Appendix F considered the carrriage on board ship of substances like naphtha, turpentine, benzoline, petroleum, &c., which readily yield vapours, which, on admixture with air, are not only dangerous on account of their explosive character, but of their inflammability and power of conveying flame considerable distances, to—it may be—vital parts of the ship or cargo. In doing this I have also directed attention to conditions *still existing* in ships of the navy and merchant vessels, which are liable to repeat these actions which occasioned the loss of H.M.S. "Doterel." I also point out that banishment of xerotine siccative merely gives no guarantee of immunity from similar accidents; but that the conditions able to

produce them will continue to be present, so long as substances containing naphtha, turpentine, benzoline, petroleum, &c., are carried as cargoes or stores, without adequate precautionary measures being *enforced.*

I have to acknowledge the courtesy of THOMAS GRAY, Esq., Assistant-Secretary to the Marine Department of the Board of Trade, who most kindly has permitted me to make use of an interesting and most suggestive memorandum, prepared by him relating to "Spontaneous Combustion of Coal, and Explosions of Coal Gas on Board Ship." I have also to thank my friend, CHARLES ANDERSON, Esq., of Manchester, for the assistance he has so efficiently rendered me in the revision and correction of proofs, &c.

THOMAS ROWAN.

MOSLEY STREET, MANCHESTER;
COLESHILL STREET, EATON SQUARE,
LONDON, S.W.:
May, 1882.

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COAL

SPONTANEOUS COMBUSTION AND EXPLOSION

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CHAPTER I.

I PURPOSE considering that action which results in what is termed the Spontaneous Combustion or Ignition of Coal, more particularly as occurring in cargoes on board ship, as well as that other danger which Coal cargoes are exposed to, viz., the explosion (under certain conditions) of Gas co-existing in Coal.

Before proceeding to do this, I shall briefly touch on the formation or development of coal in the bowels of the earth—its geological position—its varieties—and mention a few chemical facts connected with it, in so far as they may bear on spontaneous combustion and explosion. In doing this my descriptions will not be framed in the technical language of a scientific thesis, but in plain popular terms, which I trust may be comprehended by all.

ORIGIN OF COAL. Coal has been formed by the decomposition or fermentation of vegetable matter under special conditions.

The products resulting from the decay of vegetable matter vary with the circumstances under which it progresses, viz., the free or limited access of air or oxygen, the presence of moisture, and the incidents of temperature and pressure.

If the decomposition of wood takes place with free access of air, the products are—carbonic acid water, "and, according to Hermann, a small proportion of nitrogen is absorbed and ammonia generated."* If decomposition takes place with the exclusion of air, a small quantity of both carbonic acid and water are formed,

*Miller.

and marsh gas, with similar hydro-carbon compounds, are produced in considerable quantities. The component elements of living vegetable matter are carbon, hydrogen, and oxygen, and these likewise are the constituents of coal, only in different proportions and altered relations.

The examination of a peat-bog will demonstrate the gradual and progressive changes that vegetable matter is undergoing from that in which the organic structure is present, to the dense black carbonized mass resembling true coal in all but its density. The ash from peat taken from the surface does not exceed 2 per cent., while that from the bottom of the peat-bog sometimes reaches upwards of 30 per cent.*

We can also trace these changes undergone in the gradual transformation from the first variety of coal where fermentation is not completed, and where the evidences of its vegetable origin are unmistakeable, up to anthracite, where the fermentation of vegetable matter during its carbonization in the bowels of the earth has reached its utmost limits, and, as observed by Sir C. Lyell, "is so altered from its original vegetable condition as to leave scarcely any trace of its history."

The following table, extracted from Dr. Percy's work on Fuel, shows at a glance the changes that occur in the transformation of vegetable matter into anthracite :—

Table showing the gradual Changes in Composition from Wood to Anthracite.

Substance.	Carbon.	Hydrogen.	Oxygen.	Disposable Hydrogen.
1. Wood (the mean of several Analyses)	100	12·18	87·07	1·80
2. Peat (do. do.)	100	9·85	55·67	2·89
3. Lignite (do. of 15 varieties)..	100	8·37	42·42	3·07
4. Ten-Yard Coal from South Staffordshire basin	100	6·12	21·23	3·47
5. Steam Coal from the Tyne...	100	5·91	18·32	3·62
6. Pentrefelin Coal of S. Wales	100	4·75	5·28	4·09
7. Anthracite from Pennsylvania, U.S.	100	2·84	1·74	2·63

* Miller.

Thus in the decomposition of vegetable matter during its gradual carbonization, the original elements (carbon, hydrogen, and oxygen) are slowly re-acting on one another, forming with one another these compounds—marsh gas, carbonic acid, and water, and exhibiting in the different degrees of fermentation different proportions of its original elements.

That these changes have not only been carried on through vast periods of time, but have been effected under conditions of tranquility, is made evident from a geological examination of the coal deposits, where the many fossilized plants are discovered in the most perfect condition. The trunks also of the Sigillaria are in many instances found *in situ* piercing the seams of coal and superincumbent strata, with their roots in the beds of clay which lie in contact with and immediately below the coal.

Evidences, also, of an exceedingly hot climate are indicated by the fossil flora of the more ancient coal deposits, consisting mainly of large vascular plants of the Cryptogamic vegetation. Indeed I can conceive of no more fascinating page in the whole book of Nature, than that which is disclosed to us by an examination of these ancient relics and records of primeval life and vegetation with which our coal deposits are so enriched.

The late Professor Buckland remarks, in that graphic and graceful language which distinguishes his writings—"We are all brought back into immediate connection with the vegetation that clothed the ancient earth, before one-half of its actual surface had yet been formed. The trees of the primeval forests have not, like modern trees, undergone decay, yielding back their elements to the soil and atmosphere by which they had been nourished; but, treasured up in subterranean storehouses, have been transformed into enduring beds of coal, which, in these later ages, have become to man the sources of heat, and light and wealth. My fire now burns with fuel, and my lamp is now shining with the light of gas, derived from coal which has been buried for countless ages in the deep and dark recesses of the earth. We prepare our food, and maintain our forges and furnaces, and the power of our steam-engines, with the remains of plants of ancient forms and extinct species, which were swept from the earth ere the formation of the transition series was completed.

Thus, from the wreck of forests that waved upon the surface of the primeval lands, and from ferruginous mud that was lodged at the bottom of the primeval waters, we derive our chief supplies of coal and iron; those two fundamental elements of art and industry, which contribute more than any other mineral productions of the earth, to increase the riches, and multiply the comforts, and ameliorate the condition of mankind."

GEOLOGICAL POSITION OF COAL. In the modern arrangement of strata now accepted by Geologists, and founded on its mineral differences and fossil distinctions, we find the coal measures embraced in what is termed the Carboniferous system. This system lies immediately above the Old Red Sandstone or Devonian system, and below the Permian system. The Carboniferous system has been divided into the lower coal measures or Carboniferous shales, the mountain limestones, and the upper or true coal measures. "On the whole," remarks Mr. Page, "the Carboniferous strata from first to last may be said to be composed of frequent alternations of sandstones, shales, fire-clays, limestones, coals, and ironstones."

"The influences," remarks another author, "which have determined the characters of the rocks that are associated with the coal beds have been so constant that not only are they identical all over the globe, but in the cases where coal beds are formed on other formations than the coal formations, the rocks of these formations abandon their special characters to borrow those we have described." (*Taylor.*)

VARIETIES OF COAL. Leaving aside the consideration of peat and the several other varieties of fossilized combustible matters, such as resin, bitumen, &c., &c., coal has been divided into three leading varieties, viz.:—

Lignite, Bituminous Coal, and Anthracite.

LIGNITE. This variety of coal is to be found in that system embracing the strata and sedimentary accumulations which lie

between the Chalk and the close of the Drift formation, called the *Tertiary system.* It is therefore of much more recent formation than common coal.

Dr. Ure has observed that "Lignites, which are manifestly bituminized wood, hold an intermediate place in the gradation between vegetable matter and pit coal. They have the fibre of the former, with the jetty lustre of the latter. Some lignites closely resemble peats in their chemical characters; others seem to graduate into perfect coal. Lignite has generally a woody aspect; coal always that of rock." Lignites all contain a large proportion of water when first raised, sometimes reaching 40 per cent., and they retain 15 or 20 per cent. of this after exposure to the air for even many months.* They vary in colour from brown to black. Some also retain their woody lamellar structure; in others this is only with difficulty distinguishable. Iron pyrites is nearly always present in the different varieties of lignite.

Bituminous Coal. This is the most abundant, as it is by far the most important, product of the British coal fields. There are a number of varieties of Bituminous coal differing considerably in their composition, and in the products they yield by the application of heat. When placed on the fire they, however, all burn with a smoky flame, of more or less luminosity. They never exhibit a crystallised fracture, and when heated in a closed vessel they leave a more or less coherent coke.

The most important varieties of Bituminous coal are—

1. Cannel, or Parrot Coal, sometimes also named Gas coal. They are of a slatey structure. When placed in a heated retort from which air is excluded, they yield a large quantity of volatile matter, in the form of uncondensable gases and condensable vapours; the residue left in the retort being the well-known gas coke. Some varieties of Cannel coal, when gradually heated with exclusion of air, yield a considerable quantity of liquid and oily hydro-carbons, with gaseous hydro-carbons of more or less density.

2. The second variety may be represented by House Coal, such as Newcastle coal, and is much valued for domestic and for

*Miller.

heating purposes generally. This variety burns with a bright luminous flame, and yields a grey-black cellular coherent mass of coke, possessing much lustre.

3. Steam Coal. This third variety approaches anthracite in quality, and represents that point where the bituminous character is verging into the anthracite. It burns freely with flame, but with little smoke, giving out a steady heat. It stands considerable pressure without crumbling, and is therefore well adapted for carriage in the holds of steam vessels. The coke it yields possesses little coherency or lustre.

Anthracite Coal. This is sometimes designated Stone coal, or Culm. It is, as we have already seen, the ultimate product of the decomposition or carbonization of vegetable matter. It is very compact and hard, burning often with considerable difficulty, and with a smokeless flame of feeble luminosity. Many varieties of anthracite, when heated, splinter into small fragments or decrepitate, and are therefore inconvenient for household purposes.

Anthracite is often iridescent, some varieties exhibiting so beautiful an iridescent play of colours as to be termed "Peacock coal." The coke obtained from anthracite differs little either in bulk or weight from the original coal. It is exceedingly abundant in North America, and we can obtain an excellent quality of anthracite from the South Wales coal fields.

The gases enclosed or occluded in coal, have been examined by several chemists of high reputation, and present a most interesting subject of study. As not being, however, within the scope of this treatise, I must refer the reader to Dr. Percy's valuable volume on Fuel, where this subject is dealt with in that thorough manner that characterises all Dr. Percy's work.

When coal is exposed to the weather for any lengthened period of time, it is found to have deteriorated in quality and value. To a great extent its calorific power has disappeared, and in some kinds of coal the caking qualities are much modified, if not altogether lost. If, however, coal is so protected as to be kept dry, this deterioration progresses but slowly.

Richters has made very elaborate investigations into what he has termed, the "weathering" of coal. His results are most valuable and interesting. In these experiments he demonstrates the power possessed by coal for absorbing atmospheric oxygen—that this varies in different coal--that "the absorption begins very soon and progresses with proportionate rapidity,"* and is accelerated by heat.

All coal is found to contain water or moisture, to a greater or less degree, when brought to the surface, a portion of which it loses when exposed to the air. The power to absorb and retain moisture varies considerably in different coal. It has been shown by Richter that this property is not dependent on its structure merely; a compact coal sometimes absorbing three times more moisture than a coal of a soft loose texture. He also showed that a relation existed between the absorbent power of coal for water and oxygen —that the more water a coal could injest the greater its absorbent power for oxygen.

* Percy.

CHAPTER II.

THE safe carriage of coal in ships is a subject of deep interest, not merely to coal shippers and those more directly concerned in its export, but to the nation at large.

If, therefore, from a study of the subject, we can arrive at the direct causes of these accidents, which render coal a most dangerous and treacherous cargo, and are thus enabled to indicate means by which coal can be conveyed in ships with safety, there can be but few more important investigations. The great importance of this question has always been recognized, and increasingly so of late. A Royal Commission was appointed by Parliament in 1875, to inquire into the spontaneous combustion of coal in ships, and in 1876 their report was issued in the form of one of the blue books. A perusal of the cases given in it will show what severe casualty constantly accompanies the carriage of coal in ships. The conclusions arrived at from the investigation of the cases of spontaneous combustion and explosion submitted to them, the result of their examination of witnesses directly concerned in them, or in the subject, and their collection of collateral evidence received from other sources, were summarized by the Commissioners in their report, under seven heads, to which I shall again refer. I will only here observe that up to the present time the risks attendant on coal carriage have not been reduced,* at least in the judgment of the Underwriters, and the premiums on underwriting coal cargoes, which in 1875 were described as being almost prohibitive for long voyages, far from being reduced, have again increased. Taking for example such a port as Liverpool, the rates since December, 1881, have increased 5s. to 10s. per cent. And at

* Page 28.

Hull the underwriters decline to quote for long voyages unless for "sporting risks."

The dangers to which the carriage and stowage of coal are subject, are twofold, viz.:—

Spontaneous Combustion and Explosion.

I shall proceed to investigate these points, and to draw attention to what in my opinion is necessary to be effected in order that coal on board ship may be conveyed with immunity from disastrous accident.

SPONTANEOUS COMBUSTION. The result of all sound research into those chemical changes which cause (so called) spontaneous combustion or ignition of coal, is to demonstrate that it can arise from two sources.*

1st. The oxidation of some of the sulphur compounds existing in coal.

2nd. The absorption and condensation of atmospheric oxygen by the carbon pores of coal—otherwise carbonaceous oxidation.

Under certain conditions, which we will examine, both of these actions take place, accompanied with the evolution of heat, and, if carried on with sufficient energy, such elevations of temperature can be induced as to result in the ignition or combustion of the coal.

Sulphur† in coal is found in two forms of combination—as a sulphide, as in pyrites—or as a sulphate, as in sulphate of lime. In the latter form, it is stable, and being already completely oxidized, it cannot develop heat. The chief, if not the only form of sulphur in coal which gives rise to spontaneous combustion, is its combination with iron, known as iron-pyrites, or "brasses." This combination of sulphur is more or less present in every variety of coal. Sometimes it occurs in massive forms or laminæ, sometimes in fine filaments, and sometimes in minute crystals. Pyrites is known to exist in the mineral kingdom in the cubical form, having

*The oxidation of the "disposable hydrogen" has been suggested as a probable source of heating—this, however, as yet, is merely hypothetical.

†Sulphur may exist in combination with the organic elements of coal, but the exact relations that may be established between them is unknown.

a bright yellow colour—or in the prismatic form exhibiting a white metallic appearance. With the varying physical conditions under which pyrites exist in coal, so does its stability alter some forms of pyrites readily commencing oxidation on free exposure to the atmosphere, while others require some exciting cause—such as heat—before oxidation begins. In all cases, *moisture* promotes this oxidation, if indeed its presence is not absolutely essential to its taking place at all.

The oxidation of pyrites is always slow, and its rate of progression is also commensurately slow. This action has therefore to be conducted on sufficient *mass* before the accumulated heat can so accelerate the oxidation as to arrive at temperatures requisite for ignition.

We have already seen that coal has the power, more or less, of absorbing atmospheric oxygen. With some varieties of coal the action can also result in ignition. This occurs with charcoal, if stacked soon after its preparation; the highly porous structure of the charcoal offering especially favourable conditions for rapid absorption.

Coal presents great variety in structure and texture, some being open and porous, others compact. Some varieties are soft and friable, crumbling with friction or pressure; others again can resist considerable pressure without disintegration. In my opinion, however, the mechanical conditions as presented in the average size of the lumps of which coal cargoes are made up, and the proportion their quantity bears to the amount of small coal mixed with them, are not such as tend, unaided, to promote carbonaceous oxidation with sufficient rapidity to cause ignition; and, therefore, in the majority of cases, the spontaneous combustion of coal on board ship has, in the first instance, been due to other causes. The experiments of Richters show that coal, under certain conditions, can spontaneously ignite from solely carbonaceous oxidation.

The following table, which I have taken from Dr. Percy's work on "Fuel," shows the results of Richters' experiments on the ignition of coal from carbonaceous oxidation. I will also give Dr. Percy's observations regarding them—"In a lecture delivered

in 1864 I used these words when speaking about coal: 'I am disposed to believe that there is another cause of spontaneous ignition (besides iron-pyrites) similar to that which determines the spontaneous combustion of cotton waste, viz.:—the absorption of oxygen by coal reduced to a fine state of division;' and I had often previously stated the same view in my lectures at the Royal School of Mines. . . . . It was reserved for Richters to substitute fact for opinion, and to demonstrate by experiments—which, in my judgment, are conclusive—that, generally, the spontaneous ignition of coal is due to the heat developed by atmospheric oxidation of the organic substance of coal, and not to that resulting from the oxidation of iron-pyrites. He has shown that coal most liable to spontaneous ignition is not that which contains most iron-pyrites; and of this proof is afforded by the following table, in which he has arranged eleven varieties of coal from the carboniferous system, in three classes, according to the degree of their self-inflammability :—

Table of Coals arranged according to degree of Self-Inflammability.

Degree of Self-Inflammability.		Iron Pyrites, per cent.	Water, per cent.	Character of Coal.
Class I. Difficultly Self-Inflammable ...	1	1·13	2·54	Easily friable.
	2	from 1·01 to 3·04	2·75	Very compact.
	3	1·51	3·90	Do.
Class II. Of Medium Self-Inflammability	4	1·20	4·50	Firm, schistose, bright.
	5	1·08	4·55	Hard, but very brittle.
	6	1·15	4·75	Moderately tender.
Class III. Readily Self-Inflammable ...	7	1·12	4·85	Outwardly very like No. 1.
	8	1·00	9·01	Moderately tender, schistose.
	9	0·83	5·30	Moderately soft, schistose.
	10	1·35	4·85	Do.
	11	0·84	5·52	Not stated; yielded only 25 per cent. of ash. From the same pit as No. 10, but from a different seam, remarkable for its great self-inflammability.

Atmospheric oxidation of iron-pyrites is always a comparatively slow process, and, consequently, there must be much loss of heat. It is not, however, asserted that iron-pyrites may not, when present in coal in considerable quantity, develop sufficient heat during its oxidation by atmospheric air to set the coal on fire."

Dr. Percy is, without doubt, one of the highest authorities, and one of the most accurate investigators and experimentors we have. Yet, with deference I submit, that, before such deductions can be assumed as revealing the cause or origin of the spontaneous ignition of coal in ships, it must be demonstrated that similar results can be obtained when operating on coal under the very altered conditions that *size* and *bulk* present. As Dr. Percy has observed, it is well known that the atmospheric oxidation of iron-pyrites is a comparatively slow process, and that consequently there must be much loss of heat. It is required—as I have already noticed—that this action should be conducted in bulk before the accumulated heat can accelerate oxidation sufficiently to develop temperatures requisite to reach the point of inflammability. On the other hand, we have it stated that the carbonaceous absorption of atmospheric oxygen by coal "begins very soon and proceeds with proportionate rapidity." There can, consequently, be no such loss of heat as that which takes place with pyritic oxidation. Operating therefore merely on samples of coal *in a fine state of division* we have the conditions for promoting heating from carbonaceous oxidation, and in the *absence of bulk* we have conditions most unfavourable for heating from pyritic oxidation. In coal cargoes we have the carbon in *lumps*, and a mass of pyrites, in a more or less finely divided state, disseminated through the coal. These conditions are therefore very different from those under which the results above tabulated were obtained.

I will take the opportunity of giving here a letter published in the Commissioners' Report at page 109 Appendix, from Professor Ferguson, of Glasgow University :—

University of Glasgow,
May 16th, 1876.

Dear Sir,

In reply to your favour of 15th inst., I beg to send you the results of my examination of four samples of coal furnished me by Mr. John Ferguson, of Whiteinch. You will observe that I have confined my examination to the general composition of the coals, in so far as that seemed to me to bear on the question of spontaneous combustion. No. 1 is Ell coal from the Hamilton Coal Company; No. 2 is Ell coal from J. Watson; No. 3 is Ell coal from Roughrigg; No. 4 is Russell's Splint. The numbers express percentages.

	No. 1.	No. 2.	No. 3.	No. 4.
Moisture	8·15	6·55	1·60	6·30
Ash	19·50	17·20	2·90	7·20
Coke	59·24	55·88	67·10	57·12
Sulphur (Total)	14·66	10·84	0·809	0·589
Iron	5·68	5·42	Trace	Trace
,, Pyrites	12·17	11·61		

Nos. 1 and 2 accordingly contain much pyrites; indeed, the mineral was quite apparent in the coal; Nos. 3 and 4 are practically free from pyrites.

In order to ascertain to what extent the pyrites in the coal undergoes oxidation, I made one or two experiments with the following results. Portions of the coal were taken, and the amount of oxidized sulphur (assumed to be sulphuric anhydride—SO_3—entirely) present estimated. The coals were then spread out to the air, one part being kept dry, another being moistened from time to time. Portions of these were taken at intervals, and new determinations of SO_3 in them made. The numbers again denote percentages.

	No. 1, SO_3.	No. 2, SO_3.	No. 3, SO_3.	No. 4, SO_3.
In original sample at 21st Dec., 1875	0·198	0·218	*Nil*	*Nil*
After exposure, moist, till 21st Jan., 1876	0·280	0·346	...	...
After further exposure till 24th Jan. 1876	0·308	0·390	...	...
After exposure, dry, till 21st Jan., 1876	0·311	0.307	...	...
After further exposure till 24th Jan., 1876	0·342	0·350	0·034	0·099

A portion of No. 2 was also kept in air for a week at a temperature of 104° Fahr., at the end of which time the SO_3 amounted to 0·548.

These numbers, if they are of any value at all, (for in an experiment on so

small a scale, and for so short a time, the smallest accidental circumstance might produce considerable variations and anomalies, which could be got rid of only after many repetitions), show that the oxidation was most rapid at first. Thus No. 1 in the dry state increased at first from 0·198 to 0·311, that is by 0·113; afterwards it increased from 0·311 to 0·342, or by 0·031 only, and similarly with all the others. It is observable that No. 1 moist oxidized less rapidly than when dry, whereas No. 2 oxidized at first more rapidly than when dry. The results therefore with regard to dampness of the coal are contradictory. The oxidation of the pyrites appears to go on slowly and at a diminishing rate.

The only other inference that forces itself upon us is, that if all four are samples of coal that have caught fire spontaneously, it can hardly have been due to the oxidation of pyrites alone, seeing that No. 3 and No. 4 were free from that substance.

My opinion is that conclusions of any worth could be arrived at only after very many experiments on different kinds of coal, placed under varying conditions of temperature, &c., and that great care is requisite in interpreting the results of two or three experiments like the above. The next point to examine is the extent to which the carbon and hydrogen of the coal itself undergo slow oxidation, and whether spontaneous combusion is not due to that action.

I am, &c.,

JOHN FERGUSON.

The remarks made with reference to Richters' experiments are equally applicable here, but it is observable that Professor Ferguson himself cautions any conclusions from his experiments being readily accepted as a solution of the action of spontaneous ignition of coal cargoes. In these observations I have made, I am far from seeking to undervalue the great importance of Richters' or similar investigations, or to divert the direct bearing they may have on the action of the spontaneous ignition of coal on board ship. Nor do I desire to demonstrate that when ignition has occurred, it has not been attributable in many instances to other causes than the oxidation of iron-pyrites. What I do affirm is, that from the *facts* disclosed to us in the Report of the Royal Commissioners, connected with the spontaneous combustion of coal cargoes, the evidence establishes that in the majority of cases, chemical action has been first set up by the oxidation of the iron-pyrites in the coal.

Let us descend, however, from the regions of theory and experi-

ment—valuable undoubtedly as they are—to the very stern and practical facts presented to us by these cases of spontaneous combustion in ships, given minutely in the Commissioners' Report. In commencing to do so, I will remark, that in accepting the evidence of witnesses on this, as on other scientific subjects, when they possess little scientific or chemical training, but insignificant value can be attached to any mere opinions or surmises expressed by them. When, however, they can attest actual facts, their evidence becomes of the highest importance, for in dealing with coal cargoes, I must again observe, we have not the conditions present that laboratory experiments on pounded samples are conducted under, but on masses of material. It is well enough known to practical chemists that operations directed against bulk, give often widely different results from those arrived at in laboratory manipulations.

If the observations I have made are sound, in reference to the influence exercised by bulk in determining ignition from pyritic oxidation, we should expect, that in actual experience it would be found, that the larger the coal cargo, the greater would be its liability to spontaneous combustion. This is so, and the information afforded us by the Royal Commissioners' Report settles this question beyond controversy. The following is from their Report (p. 7.)—

> Again this return shows, to a startling extent, that the proportion of casualties traceable to spontaneous combustion increases *pari passu* with the tonnage of the cargoes. This becomes still more apparent when the European trade is deducted. The return then shows that there were, in 1874—
>
> 2,109 shipments, with cargoes under 500 tons, in which 5 casualties occurred, or under ½ per cent.;
>
> 1,501 shipments, with cargoes between 500 and 1,000 tons, in which 17 casualties occurred, or over 1 per cent.;
>
> 490 shipments, with cargoes between 1,000 and 1,500 tons, in which 17 casualties occurred, or 3½ per cent.;
>
> 308 shipments, with cargoes between 1,500 and 2,000 tons, in which 14 casualties occurred, or over 4½ per cent.; and
>
> 77 shipments, with cargoes over 2,000 tons, in which 7 casualties occurred, or 9 per cent.
>
> The casualties in vessels bound to San Francisco were the most remarkable

Deducting vessels under 500 tons (in which no cases of spontaneous combustion were recorded), the return shows 9 casualties out of 54 shipments. These also increase in proportion to the tonnage of the cargoes, till we arrive at the alarming fact that out of the 5 ships with cargoes of over 2,000 tons sent to San Francisco in 1874, 2 suffered.

Again, with reference to carbonaceous oxidation, it is only asserted that *some varieties of coal* are liable to spontaneous ignition from this source. In Richters' experiments it will be observed that while he found *some varieties* easily inflammable from carbonaceous oxidation, others again he found to be more or less stable. It is therefore evident that if carbonaceous oxidation be the cause of spontaneous ignition in coal cargoes, we should find that only certain varieties of coal have ignited on board ship. From the Commissioners' Report we learn that the very reverse of this has been manifested by actual experience, and that spontaneous combustion has not been confined to any one class of coal, but has occurred in nearly all the varieties that have been exported from this country. In giving evidence on this subject before the Commission, Mr. R. Cooper Rundell, one of the Secretaries of the Underwriters' Association of Liverpool, states from statistics especially prepared as follows* :—" The fires have not been confined to one kind of coal, but have occurred in most, if not all the different varieties usually exported. In fact, the inquiries which have been made support the opinion that no kind of ordinary coal containing hydrogen has immunity from spontaneous combustion. Thirdly, we find that the fires occur in the cargoes whether the coal be loaded in summer or winter, by tip or by basket."

To proceed further with our investigation :—we find that in the majority of cases of spontaneous combustion given in the Report, the coal has been shipped wet or damp, or has become so after

* Appendix to Royal Com. Report, p. 143—47.

shipment. Indeed, *wet or dampness* has been the one condition beyond all others to which those having practical experience of the heating or firing of coal in mass, have assigned that action, in conjunction with the presence of iron-pyrites in the coal. And it was testified to, that the same coal taken from the same working, when protected by covering from rain, remained cool—while another portion of it, uncovered and getting wet, had spontaneous ignition set up.*

I have taken **40** † cases of spontaneous combustion or heating of coal cargoes, commencing at page 85 of the Appendix to the Report of the Royal Commissioners. I would have taken all the cases given there, but the information on this point was either omitted, or not explicit enough. Out of these 40 cases, in 28 instances the coal was shipped wet or damp, or became so. In 8 instances the coal was brought fresh out of the pits when put on board, and therefore presumably damp. Out of the 4 remaining instances, 3 only were cases of heating where the cargoes were not destroyed. And, in the remaining one case that did result in combustion, the coal was described as being very small and dusty.

Now the presence of moisture is not a condition favourable to carbonaceous oxidation, as by it the carbon pores are filled, and consequently their capacity for the reception of oxygen is proportionately diminished. Moisture, however, highly favours and promotes the oxidation of pyrites, as we have already noticed. The weight of evidence in this respect is therefore against carbonaceous oxidation being the exciting cause of combustion. In nearly every case where the composition of the coal shipped could be ascertained in which ignition had taken place, iron-pyrites was affirmed to be present.

To pass on to the consideration of yet another point. When the heating of coal in cargoes has been observed in time, and energetically dealt with, it has been found always to commence

*Appendix to Royal.Com. Rep., p. 226. 2748.

† See Appendix A.

at some particular *spot* in the cargo, which seemed to form a nucleus from which the action spread upwards, extending as it rose. This starting point has been found at all parts of the cargo. Some of the witnesses before the Commission spoke of it as being found most frequently under the hatches, where from the usual method of loading, the small coal and coal-dust accumulates. It must be observed that while this condition is not unfavourable to pyritic oxidation, it especially favours carbonaceous oxidation. But spontaneous ignition has been observed to commence at all parts of the cargo, from the kelson to near the surface. When carbonaceous oxidation is the exciting cause of combustion we should expect to find no such uncertain localization, but that it would either *invariably* occur under the hatches, where the small coal accumulates; or that its starting would not be limited to some point or spot, but would encompass and be general in its commencement over the surfaces most accessible to the air, although protected from draught. I must add, however, that I think it is most probable that cases of heating that occur *immediately under* the hatches, may be due to carbonaceous oxidation.

In fine, from a careful examination and comparison of the cases of spontaneous combustion of coal cargoes given in the Royal Commissioners' Report, I think it is demonstrated that in the majority of the cases, ignition has been inaugurated by the oxidation of the iron pyrites, commencing at some particular, although capricious spot; that the heat so generated has gradually accumulated, and accelerated the oxidation, and that sufficient heat has been transmitted to start (it may be) carbonaceous oxidation as well; that in the confined conditions of the coal holds, where this has been taking place, the heat so produced has likewise determined, in parts of the cargo, the destructive distillation of the coal, evolving thus, products of a highly inflammable and explosive nature; and these actions have often finally culminated in the cargo's suddenly "bursting out into flames all over." This has frequently been preceded by explosion, and sometimes also followed by repeated explosions even after all the hatches have been blown off.*

The *indications* given of combustion taking place in coal car-

*Appendix Roy. Com. Report, p. 18. "Waverley."

goes have been, on the whole, constant, varying only with the time they were observed before general conflagration took place, and modified by the locality in the cargo where ignition was set up.

1. Heat was observed, and this might cover a period of from 10 to 15 days or more. When the temperature increased beyond a certain point the next indication was,
2. A slight smell of "gas" increasing in intensity, and accompanied by whitish smoke. This rapidly increased, and
3. Smoke appeared in dense and increasing volume, with a pungent and suffocating smell of "gas," which with great rapidity resulted in
4. General conflagration, with more or less explosion. The occurrence and frequency of the explosions being determined by the locality where ignition commenced. The nearer the surface the less likelihood of explosion.

The smell of the "gas" alluded to has been described by various witnesses as being similar to "paraffin oil," "naphtha," "coal tar," "sulphur smell," and like ordinary gas (coal gas). This has undoubtedly been due to the destructive distillation the coal was undergoing in the holds.

I must also remark here, that the readiness with which some varieties of schistose, or shaley coal—when exposed to sufficient heat—will yield volatile and inflammable products, igniting at comparatively low temperatures, has led some observers (from but a superficial knowledge of the subject) to attribute the *cause* of spontaneous combustion in some way or other to the evolution of these products. They can never be the *cause* of such heating, but its *effect*. It can be readily understood, however, that coal of such nature becomes much more dangerous as a cargo when either pyritic or carbonaceous oxidation has been started, and the ultimate consequences much more disastrous.

When I had written so far, my attention was directed to a work published in 1878 by J. W. Thomas, F.C.S., entitled "A Treatise on Coal, Mine-gases, and Ventilation," in which the author devotes a chapter to the Spontaneous Combustion of Coal. As this treatise is of comparatively recent date, and is certainly a peculiar contribution to the subject, I shall now proceed to notice the author's researches into the causes of spontaneous combustion of coal on board ship.

Mr. Thomas does not think that the heating or combustion of coal on board ship is due to pyrites. To quote, however, the author's own words—"As a rule, however, pyritic coal is not the subject of spontaneous combustion on board ship, because the mere fact of a coal containing much pyrites indicates that it is of little value in a commercial point of view, and it is only the better class of coal which is selected. In some rare instances, (!) it may be that cargoes have been shipped which contain a very appreciable quantity of pyrites, because it is present in some of the best seams of coal in laminated veins, between shale or top divisions or layers; and in seasons of briskness in the coal trade—which unfortunately is not at the present time—and through the negligence of proper supervision, pyritic coal may become shipped."

The author then briefly alludes to those experiments of Richters' we have already examined, and proceeds as follows:—

"The fact that the more anthracitic coals, exclusive of the percentage of sulphur which they contain, are less liable to undergo spontaneous combustion than the more bituminous, throws some light upon the subject, and it is evident that the bituminous character of the coal has a great deal to do with it." In elaboration of this, a little further on the author states—"The bituminous kinds of coal, and not unfrequently the free burning hydrogenised varieties, which contain very little oxygen, hold enclosed in their mass (!) volatile oxidisable matters which escape from the coal, or rapidly undergo oxidation when piled in large heaps. It is to these bituminous or volatile hydro-carbon matters containing oxygen, that the primary action of starting oxidation is due, and, as soon as a

moderate heat is generated, more or less of the whole mass of coal takes part, and generates further heat, until the igniting point may be attained."

Previous to these remarks, the author, when brought face to face with the spontaneous combustion of freshly prepared charcoal, assigns that action to purely *mechanical effects!* and states that the velocity with which the air is made to traverse the capillary channels forming the pores of the charcoal, gives rise *by friction to the heat of combustion (!)*

When the author treats of the spontaneous combustion of coal on board ship, it will be observed, that, if possible, he gets more involved and obscure in his statements. Dealing with coal cargoes, he says—"We are not prepared to solve the problem, but simply to make the following remarks and suggestions. All coal contains a certain proportion of water or moisture, in quantity mostly in excess of that which was present in the seam or vein, and organic matters when stacked in large bulk in a slightly moist condition undergo a kind of *sweating* action*

* By the term "*sweating* of moist organic matters," the author manifestly means the conversion of the moisture into vapour, or in other words the evaporation of the water. "Sweating," far from contributing to any elevation of temperature, will occasion exactly the opposite result—viz., a reduction of heat. It cannot, therefore, be the origin of, but the effect produced by heat already established. Again, when he speaks of "combined oxygen" exercising considerable influence, he evidently means the air that is merely held mechanically by the pores of the coal. It is certainly known to chemists that there are substances having oxygen in a loose state of combination, a portion of which they can be made to readily part with, but we have yet to learn that such exist in coal.

The author constantly indulges in general statements of the most vague character, and without attempting to advance evidence in support of them. Thus, again, in this paragraph he states, "If the coal is a porous one oxidation proceeds," &c. Oxidation of what? Is it the pyrites?—or the carbon?—or those "volatile hydrocarbon matters containing oxygen?" Again he states, "It is possible that the time which expires from the loading until the ship commences the voyage is a very important consideration." Why? What are these important considerations? It is true he adds, "Because the rolling motion of the ship continually produces fine dust by attrition, and continually liberates traces of oxidisable matters [these oxidisable matters again!] pent up in the pores," &c. But what possible connection that can exist between the "time that expires from the loading until the commencement of the voyage," and "the rolling motion of the ship" is certainly not intelligible to ordinary apprehension.

with the formation of heat, during which the oxy-compounds in the coal become partially dissociated or decomposed. If the coal is a porous one oxidation proceeds, and according to the amount of air which permeates the bulk, and the time which expires from the period the coal is shipped until the vessel goes to sea, together with the character of the coal, and the length of the voyage, the temperature of the mass may continue to rise or gradually cool down. It is possible that the time which expires from the loading until the ship commences the voyage is a very important consideration, because the rolling motion of the ship continually produces fine dust by attrition, and continually liberates traces of oxidisable matters pent up in the pores, and brings the bulk of the coal into a condition calculated to retain the heat generated. Again, the amount of combined (!) oxygen is another important item which possibly exercises considerable influence.

"If the temperature of the mass could be kept down during the *sweat*, and until the small quantity of volatile matters (?) had undergone oxidation, there would be little fear of spontaneous combustion occurring after." *

The author next proceeds to state the means he would suggest to prevent spontaneous ignition taking place in coal cargoes. In doing this, he calls attention to the Report of Dr. Percy and Professor Abel, published in the Report of the Royal Commissioners. I shall here give that passage from it that is alluded to.

"As regards the application of ventilation with a view to reduce the liability to spontaneous *ignition* of a cargo of coal, the only useful object which could *possibly* be aimed at by ventilation would be the rapid abstraction of heat developed in the coal (by chemical changes set up as described) by causing cool air to circulate freely and rapidly throughout the *body* of a mass of coal. The attainment of such a result, even by powerful means of artificial ventilation, elaborately applied, and with the coal in the mechanical condition most favourable to its free permeation by air, appears, to say the least, very doubtful, and there can be no question that any system of ventilation practically applicable on board ship would fail to attain such a result, even disregarding the fact that the mechanical (finely divided) condition of much of the coal constituting a cargo is quite antagonistic to the free passage of air through its mass.

* See foot note to p. 24.

"It does not appear practicable, therefore, to apply ventilation with any prospect of guarding against the accumulation of heat in some portion of a cargo of coal.

"Such circulation of air as may be established even in the less compact portion of the cargo is not likely to have any valuable cooling effect, and the circulation, if there be any, must be very feeble among the more closely lying masses of small coal, so that heat, if developed in these, will accumulate undisturbed. Indeed, its development would possibly be favoured by the fresh supply of oxygen which a gradual replacement of the air surrounding those parts would convey, so that a period would be reached, sooner or later, when the development of heat would be most seriously promoted by ventilation, some time before actual ignition demanded the total exclusion of fresh air.

"The evidence which has been submitted to the Committee on the subject of the ignition of coal cargoes bears out generally the conclusion to which the above considerations lead, namely, that it is inadvisable to attempt *through ventilation* of cargoes in coal-laden ships."

In face of this, and entirely ignoring the mechanical difficulties of ventilating coal cargoes so forcibly put by such authorities as Dr. Percy and Professor Abel, the author advocates through ventilation. He says, "To the latter portion we entirely agree, and if considerable heat is generated, ventilation would only act as fuel or assist oxidation, but we urge that ventilation well applied in the first instance would prevent heat."—He next refers to the invariable success that has attended his several efforts in the direction of ventilating wheat ricks, hay stacks, &c., so as to prevent their heating. He describes his plan for so doing by the aid of a diagram. His plan consists in having a wooden pipe 10 to 16 inches square, having the top perforated; this is laid horizontally at the bottom of the stack, &c. From this, he has 3 upright square pipes perforated on all sides. One of these pipes rises from the centre of the horizontal pipe, the other two pipes rise from either end of it. He states that when the temperature rises, a self-acting current is generated up the centre pipe, "which becomes stronger according as the temperature rises, owing to the heat being greater in the centre than near the ends, and the centre pipe may, therefore, be likened to the upcast shaft of a coal mine."—He then proposes to apply a similar arrangement to coal cargoes as a panacea for all the

ills that such cargoes are heir to. He says, "As shown, the wooden pipes are not carried through the rick, because under the thatch the hay remains soft, and the air can circulate; but in the hold of a vessel the coal could be ventilated on a somewhat similar principle, only it would be better (!) to carry the ventilating tubes through the deck, and have the centre one in connection with a fan worked by a windmill or other contrivance."

It would be *better* to carry the tubes *through* the decks!! How otherwise does the author expect that any circulation could take place if the pipes were *not* through the deck? In accordance with what physical law, or by what mechanical effort, could his currents pass freely through that thickness of material of which decks are usually made? But, to be sure, if his assertion commences with the qualifying terms, "it would be better," he concludes it with the employment of a windmill.

The author then closes this remarkable contribution to the literature of the spontaneous ignition of coal cargoes as follows:—"If by some such arrangement, a cargo of coal was thoroughly (!) ventilated for the first week after the coal was shipped, there would, we think, be little risk of spontaneous combustion occurring afterwards,* provided the coal had an air course at or near the bottom of the cargo. During the first week after the coal was shipped, there would be much better chance to ventilate it effectually than afterwards, as it would not have settled sufficiently close to offer much resistance to air passing through the mass. If the coal is already heated,

*This is another instance of the author's rash and haphazard assertions—If what he affirms were correct, we should find that spontaneous combustion takes place within the first week or fortnight, when, according to him, the greatest chemical action takes place. How much he is at fault is evident from the fact, that the average time is 60 days from leaving port before combustion takes place. Mr. R. Cooper Rundell (Underwriters' Association of Liverpool), quoting from statistics, states before the Royal Commission (R. C. R., page 143 ap.), "An examination of the facts collected show, first, that in the cases selected for comparison no fires occurred before the 37th day after leaving port, while in one case there was no evidence of fire before the 190th day. The greater number of fires have, however, occurred about the 60th day.

and it has been stowed some time, there will be far greater difficulty experienced in cooling it, and, as before stated, fresh air will so aid in the production of heat by oxidation that the cooling effect of the ventilating current would be over-balanced. We think it probable that the presence of moisture in coal starts an incipient fermentation, and that the heat generated could be removed, and the excess of moisture too, by the aid of active *through* ventilation applied *as soon* as the coal is stowed, so as to prevent further heat being generated by oxidation, and consequently obviate any subsequent risks of spontaneous combustion occurring. The presence of water in the hold of a ship would not assist oxidation, or start the fermentative action we have alluded to, but the deposition of dew upon coal in trucks (shipped) at night, or the moistening of coal by rain, is very probable the prime mover or cause of the generation of heat."

How the author reconciles this last statement with what he has previously pointed out as the sources of spontaneous combustion—or what the nature of that transformation is, which, when once inside a ship, reduces water to a state of inertness, while outside the vessel it remains an insidious agent to promote disaster—is known only to himself. But it is unnecessary to enter into further detailed criticism here of the author's treatise, which on this subject reads more like a series of conundrums than any scientific compendium of chemical reactions. Unless the author had intimated to us that he had seen the Royal Commissioners' Report, we must have concluded that he was as ignorant of its existence as evidently he is of the *facts* disclosed in it. I would, however, recommend to his attention these four facts, as proved by it, viz.:—

1st. That spontaneous combustion has not been confined to any one class of coal, but has occurred in nearly all the different varieties usually exported.

2nd. That, instead of pyrites being present on "rare occasions," the rare occasions have been where it was absent.

3rd. That there have been more cases of spontaneous combustion on board ship where through ventilation has been carried out, than in vessels where ventilation was not attempted. In the 40 cases I have alluded to,* 37 vessels had their holds ventilated where spontaneous ignition took place; and of the 3 remaining vessels, in one instance no information was given as to whether or not there was ventilation.

4th. I would direct the author's attention to the evidence of Mr. J. Glover, of Newcastle, given in page 194 Appendix to Royal Commissioners' Report, where he will find that his theory of spontaneous combustion has not even the merit of originality, as Mr. Glover there suggested, that "the presence of volatile and highly bituminous substances" existing in some coals, might be a probable source of spontaneous ignition.

*Page 17.

CHAPTER III.

THE TREATMENT OF COAL CARGOES IN RELATION TO SPONTANEOUS COMBUSTION.

ALL these facts connected with the spontaneous combustion of coal in cargoes—the changes which produce and the conditions which promote it—must be carefully examined in order to arrive at means to prevent that action, or minimise the dangers arising from it.

The conclusions arrived at by the Royal Commission of 1875 were summarized in their Report under 7 heads as follows:—

Having completed our inquiry into the various questions embraced by the terms of the reference to us, we beg to lay before your Majesty a summary of the conclusions at which we have arrived:—

1. That certain descriptions of coal are intrinsically dangerous for shipment on long voyages.
2. That the breakage of coal in its transport from the pit to the ship's hold, the shipment of pyritic coal in a wet condition, and, *especially, ventilation through the body of coal cargoes*, conduce to spontaneous combustion, even though the coal may not be unfit for conveyance on long voyages.
3. That spontaneous combustion in coal cargoes would be less frequent, if regard were had by shipowners and underwriters to these facts.
4. That when coal is being carried on long voyages, the temperature in the various portions of the cargo should be tested periodically by thermometer, and registered in the log.
5. That, with a view to guard against explosion, free and continuous egress to the open air, independently of the hatchways, should be provided for the explosive gases, by means of a system of *surface* ventilation, which would be effective in all circumstances of weather.
6. That in order to make known the descriptions of coal liable to combustion, the Inspectors of Mines should be instructed to hold inquiry into all cases of spontaneous combustion occurring in cargoes of coal taken from their respective districts; exporters being required always to record on their specifications the denomination of the coals forming the cargo.

7. That no additional legislation with reference to the conveyance of coal by sea is required, unless for the purpose of giving effect to our proposals with regard to the inquiries by Inspectors of Mines, and to the fuller specification of coal entered outward at Her Majesty's Customs.

While the Commissioners' Report issued with the Appendix is of the highest importance—and is a collection of facts connected with combustion and explosion occurring in coal cargoes, that could hardly have been compiled by any other means—it will be observed, that, as regards spontaneous combustion, the "suggestions" as summarized are of a *negative* character. Several conditions are mentioned which ought to be avoided, but nothing is said positively as to what should be done to prevent it arising.

It would be well, before proceeding further, to enquire *what has been the result of these suggestions* as far as regards the occurrence of spontaneous combustion in coal cargoes? Have such cases diminished?

By the courtesy of Thomas Gray, Esq., the very efficient Assistant Secretary to the Marine Department of the Board of Trade, I have been put in possession of a valuable memorandum prepared by him relating to "Spontaneous combustion of coal and explosion of coal gas on board ship, &c." From this memorandum it would appear that the cases of spontaneous combustion have decreased, to some appreciable extent at least. From one of the tables, prepared by Mr. Gray, given in the Appendix D here, it appears that in the *five years preceding and including* 1875 (the year of the Royal Commission) the cases of spontaneous combustion occurring in British owned vessels were 67, showing an average proportion of 0·141 cases to each 250,000 tons of coal carried. In the *five years following* 1175, or from 1876 to 1880, the cases of combustion were 58, showing an average proportion of 0·107 cases for each 250,000 tons of coal carried, or a decrease of 0·034 cases on each 250,000 tons of coal carried.

This table, however, only includes cases of combustion which have occurred in cargoes shipped in British owned vessels.

Foreign owned vessels which have left ports in the United Kingdom with coal cargoes have not been included. And it is also exclusive of cases of combustion occurring in Bunker coal. The proportion also of cases to each 250,000 tons of coal carried has been calculated on the basis of the *total quantity of coal* shipped from ports in the United Kingdom in *both* British and foreign owned vessels. Now, in the Royal Commissioners' Report, it will be seen that in 1874 the cases of combustion reported amounted to 70. Out of this number, it would appear from Mr. Gray's table that only 25 were British owned vessels, leaving unconsidered the balance of 45 cases of combustion occurring in foreign owned vessels. Again, in 1875, the cases of combustion were 26. From Mr. Gray's table, it will be seen that out of this number only 15 were British owned vessels, leaving a balance of 11 cases of combustion occurring in foreign owned vessels. It is thus apparent that unreliable results are obtained by crediting the total amount of coal shipped, with *only* the cases of combustion occurring in British owned vessels. Moreover, in this estimate, the total amount of coal shipped each year not only represents the amount exported to other countries, but also includes the quantity *coasted* from one port to another *in the United Kingdom*. Now, the quantity coasted does not fall very far short of that exported,* and from the short period of time that the coal lies in the holds of coasting vessels, cases of spontaneous combustion are almost unknown. The value, likewise, of these figures for purposes of comparison depends on whether the relative quantities shipped by British owned and foreign owned vessels have been *equally* maintained in *each year*.

Notwithstanding this, however, there is sufficient evidence afforded by Mr. Gray, in his memorandum, to show that the cases of spontaneous combustion have (so far) not increased, but rather diminished, and better results might have been shown had through ventilation been entirely discontinued. There is, however, ample evidence in it, to prove as well, that *merely* abolishing through ventilation has not, and will not, by any means effect a cure. And certainly the aim in dealing

*Appendix E

with spontaneous combustion is not simply to effect amelioration of the evil, but the thorough removal of it.

In proceeding to indicate the means I would adopt with coal cargoes, I must first observe that the conclusions arrived at as to through ventilation I thoroughly endorse, atmospheric oxygen taking, as it does, so prominent and essential a part in those changes, which result in ignition. Also, that the coal should be shipped in as large lumps as possible—that is to say, that means should be adopted for loading ship by which the coal suffers least breakage, and the accumulation of small coal and dust in any one portion of the cargo is prevented.

In addition to all this—

FIRST, I should have a system of ABSTRACTORS (as already advocated by me) scattered throughout the coal holds, and at different levels amongst the coal, these Abstractors being brought into action as occasion arose, and this could be determined by thermometric indications from thermometers placed in the Abstractors themselves.

If any chemical action were taking place, the gases so evolved could be drawn off by means of these Abstractors, and the danger arising from the *contact* of the heated products of incipient combustion lodging amongst the body of the coal, and thus inducing or exciting action of a similar nature in other parts of the cargo, be avoided. To prevent air making its way down through the body of the coal, the surface Abstractors could always be brought into operation when abstracting from below, and might also be worked at a greater pressure.

SECOND. In addition to this, when coal is intended for shipment on long voyages, or when it is known to be "*intrinsically dangerous*," I should treat it as follows:—

The coal should be taken from the pits in shallow iron waggons, with perforated or open bottom and sides—say lattice work, or similar construction. Prior to shipment, these waggons (with their contents) should be run into properly constructed stove-houses, and there subjected to the action of heated air, from say 150 deg. F. and upwards—varying from 24 hours to 7 or 8 days—the time and temperature being, of

course, dependent on the nature of the coal under treatment. It should then be allowed to cool, protected from the influences of the weather.

By these means the *carbonaceous oxidation* of the coal would be artificially excited, and promoted up to a point when any further action on board ship from this source could never be energetic enough to cause much appreciable heat, if any.

This treatment would also insure damp or moisture being driven off, and thus the possibility of *pyritic oxidation* taking place would be *reduced to a minimum*. At the same time, a very considerable portion of the fire-damp existing in the cells and pores of the coal would be expelled, and therefore the *liability of explosion* would be reduced by the quantity of fire-damp so driven off.

It is highly suggestive that no cases have been recorded of spontaneous combustion occurring in cargoes of patent fuel. Several witnesses before the Royal Commission testified to its stability in this respect. Now these patent fuels are prepared from crushed or disintegrated coal, agglomerated by either pitchy or farinaceous matter, and when compressed into moulds are dried in ovens. Doubtless the action I have just described takes place, and not only is the moisture or the volatile portion of the pitch or tar expelled, but carbonaceous oxidation also takes place.

In conclusion, I am convinced that if the means I have thus indicated be employed—even that class of coal now regarded as most dangerous and unfit for shipment can be carried on long voyages with immunity from catastrophies arising from spontaneous combustion.

CHAPTER IV.

THE TREATMENT OF COAL CARGOES IN RELATION TO THE EXPLOSIONS OF GAS FROM COAL.

I SHALL now proceed to consider briefly the nature of that gas from coal which is the occasion of explosions in ships carrying such cargoes.

Explosion is perfectly distinct from spontaneous combustion, and arises from a different cause. Explosion is entirely due to the liberation from the cells and pores of the coal, of that gas known by the names of fire-damp, marsh gas, light car, buretted hydrogen, methyl hydride, &c.

Marsh gas, or fire damp, as we have already seen, is one of the products of the decay of organic substances under certain conditions. It also results from their destructive distillation. It is inodorous, colourless, without taste, and sparingly or little soluble in either water or alcohol. There is no reagent that absorbs it. Equal volumes of marsh gas and chlorine will explode after exposure for some time to sun light. If moisture be present, chlorine converts marsh gas into hydrochloric acid, carbonic acid, and carbonic oxide.*

With reference to coal cargoes, marsh gas only becomes explosive when mixed with certain proportions of air, and requires the application of a high red heat before an explosion can take place. The most violent explosion takes place when 1 volume of marsh gas mixes with 2 volumes of pure oxygen, the products of the explosion being carbonic acid and water. The calculated force exerted by the explosion of this mixture equals 555lbs. on the square inch.† As the atmosphere contains only 20 per cent. or one-fifth of its volume of oxygen, it requires, therefore, 10 volumes of air to 1 volume of marsh gas to reach its greatest explosive force, and then it is much modified

* Watt's Dictionary. † Bloxam's Chemistry.

by the dilution of the oxygen with the large quantity of inert nitrogen (8 volumes) mixed with it. It is calculated that the force exerted by the explosion of 1 volume of marsh gas with 10 volumes of air, equals 210lbs. on the square inch.* When the relative proportion of air with marsh gas exceeds 10 volumes, the explosive force becomes weaker, and reduces in power with each additional volume of air present, until the proportion reaches 18 volumes of air to 1 volume of marsh gas, when the mixture will no longer explode—on the contrary, will burn quietly. Again, when the proportion of marsh gas is greater than 1 volume to 10 volumes of air, the explosive force is also lessened, until with 1 volume of marsh gas to 5 volumes of air, the mixture will no longer explode, but will extinguish a lighted taper or candle placed in it.

Marsh gas, or fire damp, exists in the pores or cells of the coal in a state of more or less compression, from which it is disengaged when the surfaces of the coal are cut or fractured. From coal freshly brought to the surface this gas, in some instances, continues to be given off in considerable quantities. Explosions have frequently taken place in the holds of ships during the operation of loading, in consequence of the gas being liberated from the cells in which it was imprisoned, by the breakage of the coal in its fall into the hold, and coming in contact with an unguarded light incautiously placed.

The escape of this gas from the coal† is therefore *greatest when first placed on board ship.* After any severe motion of the vessel, it also is sometimes liberated in considerable quantities through the attrition of the coal in the holds.‡

It is to this gas, then, already existing in the cells of the coal, when mixed with a sufficient volume of air, and on the application of a sufficiently high temperature (such as the flame of a candle or lamp, &c.), that these accidents on board ship resulting from explosion is due.

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*Bloxam's Chemistry. †See Appendix C

‡The destructive force of these explosions depends on the amount of gas liberated and the volume of air it may be mixed with. In many instances the damage done is comparatively slight, at other times it results in the total loss of the vessel. See Appendix C[1].

THE TREATMENT OF COAL CARGOES TO PREVENT EXPLOSION.——I have no hesitation in affirming that explosion from this source *can be prevented*, and *ought* NEVER TO OCCUR.

The Royal Commissioners indicated that surface ventilation—that is, ventilation along the upper surface of the coal—was required to prevent accident from explosion, by thus removing the marsh gas, as, from its light specific gravity, it found its way to the surface of the cargo.

Let us enquire before proceeding to consider the preventative means to be adopted with coal cargoes, what have been the results of the Royal Commissioners' recommendations as to surface ventilation in relation to explosions in the five years which have elapsed since their publication? Have the cases diminished, or altogether ceased?

They have INCREASED. Taking the five years preceding and including 1875—as done when considering the cases of spontaneous combustion—the number of cases of explosion tabulated by Mr. Gray are 25, showing the proportion of cases to each 250,000 tons of coal carried to average 0·053. From 1876 to 1880, the five following years, Mr. Gray's tables show the number of cases of explosion to amount to 46, or an average of 0·085 to each 250,000 tons of coal carried. The *increase*, then, of cases of explosion is 0·032 for every 250,000 tons of coal carried, or, in other words, explosions have *increased over 62 per cent. on the total amount of coal carried.*

Is surface ventilation, then, useless? Certainly not; but as carried out at present it is evidently worse than useless—it is *dangerous*. To make surface ventilation effective, it must be applied in accordance with those invariable laws which determine the flow or transit of gases of different densities and temperatures, and regulate the application of propulsion and abstraction. To make a few holes in the deck of a vessel, and insert therein a few pipes, with cowls of divers shapes and fashions—some of which may be turned to the wind and *called* down-cast pipes, others turned from the wind and *supposed* to be up-cast pipes—is not ventilation.

The abstraction of the atmosphere from the surface of cargoes must be assured in harmony with scientific and mechanical principles, as well as its replacement with fresh air. And if continuous surface ventilation be proved to be best, then it should and *can be* maintained without the danger of seas being shipped through any necessary openings in the deck, however rough the weather may be. The present system of having large holes pierced in the deck for the reception of so-called ventilators which, from their construction, their position, and the surface they present to a mass of water shipped against them, are liable to be carried bodily away, is, in my judgment, in every way wrong. Sooner or later they will be the source of great disaster, by the foundering of the vessel, through seas shipped down these large openings, when their unreliable coverings are carried away. The time has now surely come when it has been sufficiently manifested that a proper system of ventilation for ships should not only be *determined* on, but *enforced;* the want of which being not alone disastrous to property, but worse—perilous to life.

There is no doubt that surface ventilation, *efficiently applied* and *carried out*, will prevent the occurrence of explosion, provided there are no cracks or fissures in the shell of the coal bunkers or holds through which the gas might escape to other parts of the vessel. But surface ventilation alone will *not remove all the fire-damp that lodges throughout the coal in the holds.* The same mechanical difficulties and conditions, as pointed out by Dr. Percy and Professor Abel, that prevent "through ventilation" being carried out in coal cargoes would also be present as regards the passage of the marsh gas from the lower portions of the cargo to the surface.

But, is there not a limit to *continuous* surface ventilation—as recommended by the Royal Commission—viz., a current of air continually passing over the surface of the coal? As regards explosion, none whatever. There is, however, the danger of spontaneous combustion to be contended with—that oxidizing action we have considered. While, therefore, the atmosphere from the surface of the coal should be very frequently removed and

replaced, more especially for a few weeks after the coal has been shipped, or in hot weather, and during and after rough weather, when there has been much movement of the ship, and, consequently, of the coal on board. I think that it may be inadvisable to have currents of air *passing continuously* over the surface of the coal in the holds.

Again, although surface ventilation may prevent explosion in the holds or bunkers, it will not prevent accidents or explosions arising from the fire-damp that may escape through any openings or cracks in them, finding its way into other parts of the ship. The gas thus liberated is not only explosive, but by admixture with air is also inflammable, and thus becomes the possible medium, when coming in contact with any open light, of *conveying flame* to parts of the vessel where explosives, such as gunpowder, may be stored; and the results may be therefore far more direful than if the explosion had been confined to the hold.*

The method which I suggest of treating coal cargoes in relation to explosion may be summarized as follows :—

1st. The very frequent removal and replacement of the atmosphere from the surface of the coal (as stated above) by properly-placed Abstractors and Suppliers.

2nd. The employment of the Abstractors throughout the coal-holds to remove the fire-damp in the lower portion of the cargo.

3rd. The thorough ventilation, by means of suitably-placed Abstractors and Suppliers, of the compartments adjoining and surrounding the coal-holds, to prevent any lodgment of fire-damp which may leak into them from the holds.

By the employment of these measures and precautions I have thus indicated, I believe that explosions on board ship can be *entirely avoided.*

I have thus endeavoured to treat the subjects we have been considering in as practical a manner as possible, for it is useless to deal with theories unless they can stand the test of these actual results and conditions disclosed to us in the cases of catastrophe to cargoes given in the Royal Commissioners' Report, and from

* See Appendix C[1]. In the case of the "Louisa Theresa," the explosion took place by the gas which came up the hatch in the Lazarette, igniting by the *fire in the master's cabin*.

other reliable sources. The prevention of spontaneous combustion and explosion is one of those subjects that requires that we should utilize alike the scientific knowledge of the chemist to investigate and suggest, the practical experience of the skipper or seaman and statistician to modify or control, and the art of the engineer to adapt and apply the results of such united efforts, that the difficulties and dangers so long incident to the shipment and storage of coal may be successfully overcome.

CHAPTER V.

THE PREVENTION OF FIRE OR EXPLOSIONS IN SHIPS FROM CARGOES OR STORES CONTAINING SUBSTANCES OF A VOLATILE AND INFLAMMABLE NATURE.

ALTHOUGH apart from the subject of coal cargoes, but as analogous to it in some of its results, and similar to it in its treatment, I have deemed it not unadvisable to consider here briefly the carriage or storage on board ship of such substances as naphtha, turpentine, petroleum, benzoline, &c., or of mixtures containing these, as in some "patent dryers" or siccatives. Similar precautions to those I have described as necessary to secure immunity from explosions of gas from coal cargoes, should be most rigorously observed with cargoes containing substances of a volatile and inflammable nature; and the compartments of any ship where such substances are carried as stores (as in war ships, &c.), should be dealt with in like manner.

Although naphtha, turpentine, benzoline, and the like, are in themselves no more explosive than coal is, yet when the vapours rising from them or from substances containing them, are mixed with air, they become most dangerous, varying from inflammability to explosive according to the volume of air they may be mixed with. For example, 1 volume of benzoline will render 60 volumes of air highly inflammable, and when mixed with half this quantity of air (or 30 volumes), the mixture becomes explosive.

The storage, therefore, of substances containing turpentine, benzoline, &c., which are volatilizable at comparatively low temperatures, and yielding thus inflammable vapours—unless guarded with special precautions is most dangerous and reprehensible. By leakage from the casks or metallic vessels containing

them, or through insufficiently-fitting corks or coverings, *small quantities* of these substances may escape and render inflammable a *considerable volume of air.* For instance, *1 cubic* INCH of benzoline will render inflammable from *4 to 5 cubic* FEET of air.* And this inflammable atmosphere, may, on contact with any open light, CONVEY *flame* considerable distances from its source (as a train of gunpowder will), the termination of which may be in a gunpowder magazine; when the results may be sufficient to blow up the strongest of our war-ships.

Accidents from the carriage or storage of such substances have frequently taken place, and have several times been the occasion of scientific investigation. But, notwithstanding that the causes or

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* In the Report of the "Explosion of Gunpowder in the Regent's Park," by Major Majendie, R.A., the following information is given in a foot note to page 20:—

"Mr. Keates deduces the further conclusion that 100 cubic feet of air would be rendered inflammable by about 18 or 20 cubic inches of benzoline converted into vapour, *i.e.*, a little over half a pint.

"Or, the proposition may be stated thus, that a given volume of benzoline in the liquid form is capable of conversion into sufficient vapour to render inflammable 8,500 times the volume of atmospheric air; or, simply and roughly expressed, one cubic inch of the liquid when volatilized will render inflammable *five cubic feet of air.*

"Dr. Alfred Swaine Taylor, F.R.S., has furnished me with some data of a similar character. He says: 'A cubic inch of liquid benzoline (specific gravity, 708) at 60° weighs 154 grains, and is equivalent by measure to half an ounce, or one tablespoonful of liquid.

"'This small quantity of liquid is convertible into 116 inches of vapour, having a specific gravity of nearly 4, as compared with air; when thoroughly mixed as vapour with 60 times its volume of air (116 + 6,960 = 7,076 cubic inches), and a lighted taper is applied, the mixture burns with a beautiful pale blue flame, and if the glass vessel containing the mixture is long and narrow there is rather a smart explosion at the end.

"'6,960 cubic inches of air are equivalent to 25 gallons, or about four cubic feet; one cubic inch of liquid in vapour will thus render combustible and inflammable about four cubic feet of air, or 25 gallons. This corresponds to a proportion of $\frac{1}{60}$th, *i.e.*, one of benzoline vapour to 60 of air. I have tried a proportion of one-fortieth ($\frac{1}{40}$th), and the results were similar. If any liquid benzoline adhered to the jar, in an unevaporated state, it gave a yellowish colour to the flame.

"'One thirty-third ($\frac{1}{33}$rd), the same result.

"'One-thirtieth ($\frac{1}{30}$th), the same result. In these last experiments the flame burned of a reddish colour towards the end, *i.e.*, after the blue.

"'One twenty-second ($\frac{1}{22}$nd), a bluish flame, mixed sometimes with red.

"'One-fourteenth ($\frac{1}{14}$th), burned with a yellowish flame, slightly explosive towards the end.

"'The application of a lighted taper to proportions thoroughly mixed with air, in which the vapour was from $\frac{1}{8}$th to $\frac{1}{12}$th, would be dangerous.'"

conditions producing such accidents have been unmistakeably ascertained and pointed out, they have only been made known to be straightway put out of mind again.

In the official enquiry into the loss of the "Amazon" by fire on the 4th of January, 1852, there will be found an able report by Professor Thomas Graham, F.R.S., in which he points out the danger of mixing together stores, such as oils, tallow, soft soap, turpentine, tow, cotton waste, &c., &c., some of which oxidise and heat spontaneously—he then says:—"The stowing of metallic cans or stoneware jars of either oil or turpentine in a warm place is also attended with a danger which is less obvious, namely, the forcing out of the corks of the vessels, or actually twisting them by the great expansion of the liquid oil which is caused by heat. These liquids expand in volume so much as one upon thirty by a rise of not more than 60 degrees of temperature, or by such a change as from the ordinary low temperature of 40° to a blood heat; the latter temperature may easily be exceeded in an engine room. It is remarkable that the burning, a few years ago, of a large steamer on the American lakes, which even surpassed in its fatality the loss of the "Amazon,"* was occasioned by the bursting in the manner described, of a jar of turpentine placed upon deck too close to the funnel by a party of journeyman painters, who were passengers." Professor Graham next, in pointing out the probable cause of the fire, says:

"The sudden and powerful burst of flame from the store-room, which occurred at the very outset of the conflagration, suggests strongly the intervention of a *volatile* combustible, such as turpentine, although the presence of a tin can of that substance in the store-room appears to be left uncertain. I find, upon trial, that the vapour given off by oil of turpentine is sufficiently dense, at a temperature somewhat below 100°, to make air explosive upon the approach of a light. *Any escape of turpentine from the heated store-room would therefore endanger a spread of flame, by the vapour communicating with the lamps burning in the boiler room, or even with the fires of the furnaces.*"

Again, the official report of Major Majendie, of the "Explosion

* The "Amazon" had on board a total of passengers and crew of 161—out of these only 59 were saved.

of Gunpowder in the Regent's Park," on board the canal boat "Tilbury," only shows *what still may occur* in the holds of ships.*

There was benzoline on board the "Tilbury," and there was also gunpowder. The leakage of benzoline from the casks, volatilizing into vapour, and mixing with a large proportion of air, formed, as it were, a train which conveyed a flame from a lighted stove in the cabin to the gunpowder casks in the hold, resulting in a dreadful catastrophe. Is not this highly suggestive of the probable cause† of those accidents which have but recently happened?

Major Majendie's valuable report contains some interesting experiments made at the Royal Laboratory,‡ and, as he states, they illustrate by successive developments

1st. "The inflammability of a mixture of benzoline, vapour, and air.

2nd. That such a mixture may be ignited at a distance from the source of the supply of the vapour, and when ignited will act as a carrier of flame back to the source of supply.

3rd. The rapidity with which such a vapour will form even in an imperfectly closed vessel.

4th. That in a comparatively short time the mixture issuing from a hole in the closed vessel produces an inflammable atmosphere in the neighbourhood of that hole."

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*See Appendix C[1]. The same *character* of danger has to be guarded against with fire-damp, viz.: the conveyance of flame.

†"Doterel."—See Appendix F.

‡MEMORANDUM OF EXPERIMENTS made with PETROLEUM in connection with REGENT'S PARK EXPLOSION.

SERIES A.

6/10/1874. In Royal Arsenal with Professor Abel.

(1.) A little light petroleum spirit poured into a tall thin glass vessel 11″ high; at end of about a minute flame applied, and it ignited at top of vessel and burnt down.

(2.) Poured some of the *vapour* which had formed into a large glass jar, and in 15 seconds applied a light and got a small explosion.

(3.) A few drops deposited carefully at bottom of 11″ jar, and in 20 seconds light applied. It ignited at six inches from the bottom of jar.

(4.) A few drops repeated in a 12″ jar, but using rather more spirit; in 12 seconds a light applied and ignited at top.

(5.) Some petroleum spirit placed in large jar, and light applied in 10 seconds gave an explosion; (no smoke, or hardly any).

6/10/74. Grand Junction Canal Company's Wharf, City Basin.

Was shown (by Mr. Warlow and Mr. Witton) a cask of benzoline. It was standing on its end, and although its bung was covered with a tin patch there was considerable "weeping" or leakage therefrom. The benzoline was from Leon, Clere, and Charles, 21, Commercial Street, Spitalfields. The "weeping" was rapid. In about half a minute enough came out to thickly coat a finger. Put some on pieces of sponge into a bottle. On following morning on examining the bottle I found it broken (on burning a bit of the sponge I found it very inflammable).

Transferred the remainder of the sponge to another stoppered bottle, and took it up to Dr. Keates, who, in my presence, removed stopper and applied a light, and produced a small explosion.

8/10/74. Went to Mr. Keates to Barringer & Co.'s, Hackney Wick. Mr. Barringer (junior) gave us two samples of the material, one of which was refined benzoline, the same as delivered to the Grand Junction Canal Company (and one of "naphtha.")

He said they delivered the two casks of benzoline to the Company on 14th September, and on 29th two more, because the first two had not gone. On October 7th, Mr. Hughes wrote that all four were on board the "Tilbury."

Afterwards I returned with Mr. Keates to his laboratory. Dropped 20 drops of refined benzoline into a long glass; it took about 18 seconds to drop, and at one minute from first dropping applied a light, and a sharp explosion occurred.

Then dropped 20 drops of crude benzoline into glass, almost immediately applied a light, and it burnt down, with blue flame.

SERIES B.

10/10/74. Took some of the refined benzoline over to the Arsenal, and there carried out with Mr. Abel some experiments in his laboratory; temperature 61° Faht.

(1.) (This had been commenced by Mr. Abel before I came) with petroleum spirit.

Placed some in a saucer in a box, 20½ inches × 8¾ inches × 5¾ inches deep (total cubic content 1031·4062 inches = rather over half a cubic foot).

The lid was laid loosely on, and at the end of 10 minutes a lighted wax taper was slowly introduced, and on arriving at about one and a half inch from bottom of box an explosion took place throughout the box.

(2.) Same repeated, but using some of the same benzoline as was on board the "Tilbury."

Result.—A more violent explosion, and this was obtained when taper was about half way down the box.

(This experiment seemed to show that this sample of benzoline was rather more volatile than the "petroleum spirit" previously used.)

(3.) A few drops of benzoline were placed in the bottom of a glass jar 12″ deep and 1½″ wide.

At end of half a minute a taper was introduced, and at end of 9 inches from bottom explosion occurred, and flame flashed down to the bottom.

(4.) Some benzoline in saucer placed in wooden box as before. Hole

bored in end of box, and gas flame introduced. No result at end of 10 minutes (apparently volatilization not sufficiently rapid to produce explosive mixture).

(5.) The same repeated, except that the benzoline (a *little*) was poured into the box, and the gas flame applied through the hole.

After one minute
,, two minutes
,, three ,,
,, four ,,
,, five ,,
} No results.

(6.) Box cleared out. Some more spirit put in, and same repeated—no results.

(7.) A rather larger quantity of "petroleum spirit" was poured into box (three-quarters of an ounce by measure), and the gas-light held opposite to the orifice outside.

In *three-quarters of a minute* a sharpish explosion took place at the orifice (outside), and the flame flashed backwards and consumed all the spirit in the box, which was filled with flame. The explosion was sharpish, and the burning of the inflamed vapour inside was gradual. This was obtained by volatilization of three-quarters of an ounce (by measure), in space of 1,030 cubic inches, in three-quarters of a minute, the space being by no means tight fitting, and the hole through which the vapour travelled not so large as the hole caused by a small knot falling out of the wood.

SERIES C.

17/10/74. Had model of sister boat to "Tilbury" made in Royal Laboratory, on scale of three-quarters of an inch to the foot. (The man on board the boat stated that it was identical with the "Tilbury."

Dimensions of model (about)—

Stowage part	36 inches.
Width (internal)	4 ,,
Depth	$2\frac{3}{4}$,,
Mean height of roof	$1\frac{3}{4}$,,
Total depth	$4\frac{1}{2}$,,

Took the barge to Mr. Abel's office and with him made the following experiments:—

(1.) Put half an ounce of spirit (by measure) into the boat, and applied a lighted taper in the cabin at every half minute up to five minutes; again at six, eight, and nine minutes.

At nine minutes got explosion in the cabin, which ran down rapidly throughout the body of the boat, and produced a flame in the same.

(2.) Same repeated, with a small pinch of gunpowder (in brown paper) placed a little in advance of the petroleum.

Light applied in cabin at seven minutes. Got a slight "puff" in the cabin, but it did not extend.

Applied light again in cabin at 10 minutes, and got explosion and inflammation throughout boat; and in about three or four seconds this was followed by the explosion off the powder.

19/10)74. Repeated last experiment (but without powder), at inquest, and got a sufficiently considerable explosion to blow off the lid of the model.

8/5/75. Took boat to Mr. Abel's office, and there made an experiment with

it *packed* (with little imitation barrels, bales, &c.). Mr. Dent and Dr. Kellner present.

(1.) Put half an ounce of petroleum spirit on to a sponge, applied lighted taper in cabin at

5 minutes, 8 ,, 10 ,, 13 ,, } No results.
15 ,, Explosion (slight).

(2.) Then took half an ounce of petroleum spirit and poured into bow of boat; boat *not* packed.

Placed two little tufts of guncotton on floor of model.

Applied taper at 3 minutes, 5 ,, 8 ,, 10 ,, 13 ,, 15 ,, } No results.

Took off cover and found the spirit was not all absorbed or evaporated, so put on cover again, and applied light at—

17 minutes, 20 ,, 22 ,, } No results.

(3.) Had the boat thoroughly cleansed and aired.

Then put half an ounce of petroleum spirit in it in open dish, in centre, and two bits of guncotton as before.

Applied lighted taper in cabin at 5 minutes—no result.

Applied lighted taper in cabin again at 8 minutes—got explosion, which flashed through the boat and fired the guncotton.

V.D.M.

It seems almost incredible that although these conditions have been thus clearly pointed out, and illustrated, not only by scientific experiment, but by the ghastly demonstration of dire calamities, involving awful destruction to life and property—that the possibilities of such accidents taking place have not at least been minimised by *adequate* legislation.

While fully recognizing the cautious hesitation that always should mark any approach to additional legislation affecting commercial interests—and all the more when such are restrictive in character, yet it has surely now been sufficiently manifested that nothing *else* will ensure the adoption of proper precautionary measures, and certainly nothing *less* than direct legislation ought now to be resorted to.

The dreadful explosion on board H.M. ship "Triumph"* has called especial attention to the dangerous nature of "xerotine siccative," a material containing benzoline or some similar hydrocarbon. It often happens, however, that the special attention which

*See Appendix F.

circumstances direct to any one particular form of danger, may also result in the exclusion, or forgetfulness of the existence, of other evils, as much to be apprehended and guarded against. It must not be overlooked that *all substances* which readily yield vapours of an inflammable nature are in like manner, if they are not in like measure, dangerous, and are as liable, under the same circumstances, to produce similar results. The great danger to be apprehended from them all, is not so much the force they can exert by their own explosion, as the flame they may convey to vital parts of the ship or cargo.

I must reiterate the statement that an immunity from all such accidents can be secured by adopting an efficient system of abstraction and supply (such as I have already suggested and advocated), so that any of these volatile vapours, instead of being permitted to permeate the atmosphere of the ship, may be drawn off *from the locality of their production*—when such substances are either conveyed as cargoes, or carried as stores.

APPENDICES.

APPENDIX A.

AT Page 85 in Appendix to the Report of "The Royal Commissioners appointed to inquire into the Spontaneous Combustion of Coal in Ships," a list of twenty-four questions will be found, which were enclosed to Shipowners and Masters, to be filled up by them in the event of their having had experience of an actual case of Spontaneous Combustion or Explosion in Coal-laden Vessels. I have abstracted a few of these questions, with the answers returned. For the full report of these cases, the reader is referred to the Blue-book, as above.

THE FOLLOWING ARE THE QUESTIONS:—

1. Name of ship, whether steam or sailing?
2. Port of loading and destination?
3. Number of statute tons of coal shipped? Name of Colliery—if screened?
4. Date of sailing?
5. How long the coal was on board until combustion took place?
6. If ventilated?
7. State of weather at time of loading?
8. Condition as to moisture of coal when put on board?
9. The indications given of the cargo being heated before fire broke out?
10. In what part of the ship the combustion took place?

THE REPLIES FORWARDED:—

I.

1. "COLUMBIA."—Sailing vessel.
2. Liverpool—Aden.
3. About 750 tons.
4. January or February, 1850.
5. About 90 days out.
6. Ventilated—wood ventilators laid fore and aft, and up and down into the fore main and after hatches.

7. Wet while loading.
8. Wet.
9. Could find a great heat coming up the after hatch for 10 or 15 days before fire broke out.
10. Was first discovered just abaft the fore hatch.

II.

1. "ALFRED."—Sailing ship.
2. London—Valparaiso.
3. 1,050 tons, not a full cargo.
4. September, 1850.
5. 9th January, 1851.
6. Not ventilated.
7. Fine weather.
8. Seemed dry, but was a small-sized coal.
9. First indication was a smell of gas in the hold, about 48 hours before the fire broke out, next smoke gradually increasing.
10. A little before the main hatch, starboard side, about the centre of the body of the coals.

III.

1. "MARY SHEPHERD."—Sailing ship.
2. London—Shanghai.
3. Record destroyed.
4. Autumn, 1852.
5. Spring, 1853.
6. By wooden trunk alongside keelson, and two or three shafts to hatchways.
7. Wet during loading.
8. Exposed to weather in transit from Swansea.
9. Hot decks, &c., for some time before fire.
10. Believed to have been in fore hold.

IV.

1. "ADMIRAL LYONS."—Sailing ship.
2. Sunderland—Bombay.
3. 1,000 tons coal, 400 tons coke.
4. June, 1861.
5. July, 1861.
6. Two shafts—one each side, 4 feet from the bottom of the ship, connected with shafts up each hatch.
7. Wet weather.

8. Damp.
9. Noticed a little smoke coming up the ventilators a few hours only before fire, but rapidly increased.
10. Right under the main hatch, about 5 feet from keelson and close to ventilator.

NOTE.—The coals were supposed to have been brought out of the pit two days before shipment.

V.

1. "GLENLYON."—Sailing ship.
2. Birkenhead—Bombay.
3. 2,050 tons; Westminster; Brymbo double-screened.
4. 1865.
5. Twenty-two weeks.
6. Planks on the beams 4 inches apart, ventilators along each side of the keelson connected with a shaft up each hatch.
7. Fine weather.
8. Dry—but noticed much pyrites among the coal.
9. Noticed an increase in temperature of the hold for several days before the fire.
10. Right under the fore hatch about 5 feet from keelson and close to the ventilator.

NOTE.—The coals were supposed to have been brought out of the pit two days before shipment, and contained much pyrites.

VI.

1. "USK."—Sailing ship.
2. Swansea—Valparaiso.
3. About 450 tons; smelting coal; not screened.
4. 1861.
5. About 100 days.
6. In the usual manner, with wooden shafts from each hatchway.
7. Raining.
8. Appeared to be damp.
9. Only a few hours previously a great heat was felt in the forecastle, and on the fore-hatches being taken off the flames burst up as high as the tops, and the ship was immediately abandoned.
10. Supposed to be under the fore-hatchway.

VII.

1. "LOCHIEL."—Sailing ship.
2. Tayport—Calcutta.
3. 1,500 tons; Townhill Colliery.

4. 17th September, 1864.
5. 4th January, 1865.
6. Partially ventilated—wood.
7. Very bad; thoroughly wet with sea and rain.
8. Very wet.
9. Only twenty-four hours before—smoke.
10. Amidships—main hatchway.

VIII.

1. "HER ROYAL HIGHNESS."—Sailing Ship.
   Cardiff—Valparaiso.
3. 1·804 tons; Rhonda, No. 3; through and through.
4. January, 1866.
5. 5th April, 1866, cargo found to be much heated.
6. Ventilated.
7. Exposed to rain.
8. See above.
9.
10. Under main hatch.

NOTE.—Combustion did not burst out, although the cargo was found to be much heated—smoke and steam issuing from it. The ship was run back to Monte Video, where the cargo was sold.

IX.

1. "ROYAL FAMILY."—Sailing ship.
2. Birkenhead—Aden.
3. About 2,500 tons; Welsh steam; single-screened.
4. February, 1868.
5. About 72 days out from Liverpool.
6. Yes.
7. Rainy.
8. Damp.
9.
10. About 14 feet from deck in main hatch.

X.

1. "PERSIA."—Sailing ship.
2. Greenock—Bombay.
3. 1,830 tons; Wishaw coals, Lanarkshire; single-screened.
4. 1st September, 1868.
5. 31st October, 1868.
6. Ventilated with wood fore and aft.
7. Showery.

8. Coal dry. (?)
9. Heat was experienced in the poop, then in a few days smoke was seen, which increased, until decks were burning; this was followed by a violent explosion. The ship was wrapped in flames, and then abandoned.
10. Under the poop.

NOTE.—These coals were brought *direct* from pits.

XI.

1. "JANET COWAN."—Sailing ship.
2. Greenock—Bombay.
3. 1,756 tons.
4. August, 1869.
5. November 1st, 1869.
6. Three ventilators, one in main-hatchway, one in quarter-hatch, one in ventilator on top of house on deck, of 9-inch deals, with 2½-inch space.
7. Wet part of the time.
8. Seemed to be dry. (?)
9. (The description is too long to give here.)
10. In hatchways.

NOTE.—The fire was got under by removing the coal until the seat of combustion was reached.

XII.

1. "GLARAMARA."—Sailing ship.
2. Greenock—Matanzas.
3. 660 tons; Wishaw Main coal.
4. May, 1870.
5. July, 1870.
6. Partially with wood.
7. Fine weather.
8. Dry.
9. Slight smoke shown for two days before fire broke out.
10. Apparently in fore hold.

NOTE.—Coals believed to be fresh dug from pits.

XIII.

1. "MALABAR."—Sailing ship.
2. London—Batavia (Java).
3. 1,274 tons 14 cwt.; Langley Mill.
4. June, 1870.

5. 25th July, 1870.
6. Yes; horizontally on each side of keelson, and perpendicularly at each hatchway.
7. Fine weather.
8. Portion taken in wet from barge.
9.
10. Main hatch.

NOTE.—They attribute the combustion to bad quality, and damp condition of coal.

XIV

1. "L'AOUHANNA."—Sailing ship.
2. Birkenhead—Bombay.
3. 1,600 tons.
4. 10th October, 1870.
5. 25th January, 1870.
6. Yes.
7. Showery.
8. Damp.
9. By a quantity of steam rising from hold about three days before fire.
10. About main mast.

XV.

1. "CEREAL."—Sailing ship.
2. Swansea—Santos.
3. 488 tons; half, Merthyr Dare Colliery; other half, Gravesend and Gellia Cadoxton Collieries.
4. 7th August, 1872.
5. 28th September, 1872.
6. Not ventilated.
7. Rained all the time of loading.
8. Wet.
9. Felt heat about week before fire broke out. No smoke until day before flames broke out.
10. In the centre.

NOTE.—The coals were fresh wrought.

XVI.

1. "BIVOUAC."—Steamship.
2. Newcastle-on-Tyne—Odessa.
3. 1,229 tons cargo.
4. 23rd October, 1872.
5. About 10 days.

6. Yes; with galvanized iron cowled ventilators, two to each hold or compartment.
7. Wet.
8. Wet.
9. A light steam was seen a day before the fire broke out.
10. Main hold.

XVII.

1. "HENRY BATH."—Sailing ship.
2. Swansea—Chili.
3. 650 tons; smelting coal.
4. December, 1872.
5. About 70 days.
6. Yes.
7. Wet.
8. Wet.
9.
10. Under fore hatch.

NOTE.—Coal was small.

XVIII.

1. "ALPHA."—Sailing ship.
2. Swansea—Chili.
3. 650 tons; Mynyddy Bach.
4. July, 1874.
5. About 70 days.
6. Yes.
7. Wet.
8. Wet.
9.
10. Between fore and main hatchway.

XIX.

1. "COUNTY OF NAIRN."—Sailing ship.
2. —— Java.
3. 600 tons; Hamilton Coal Company; double-screened.
4. May, 1873.
5.
6. Yes. Eight 12-inch ventilators and one 21-inch of iron, all through main deck, and 3 iron mast ventilators.
7. Fine day.
8. Apparently dry.
9. Smell of gas observed the evening before fire broke out.

10. Main hatch, lower hold.

NOTE.—The coals came *direct out of pits.*

XX.

1. "COUNTY OF PERTH."—sailing ship.
2. —— Calcutta.
3. 1,600 tons; Roughrigg coal; double-screened.
4. July, 1874.
5. 114 days.
6. Yes. One 28-inch wood from main deck to bottom of hold, with iron bell mouth, and ten 12-inch iron through main deck, and three iron mast ventilators.
7. Fine.
8. Apparently dry.
9. Smell of gas observed the evening before fire broke out.
10. Near main hatch in lower hold.

NOTE.—Coals came *direct from pit.*

XXI.

1. "GEORGE DOUTHWAITE."—Sailing ship.
2. Hull—Constantinople.
3. 625 tons; reported from South and West Yorkshire pits; double-screened.
4. 12th July, 1873.
5. 6th September, 1873.
6.
7. Raining incessantly.
8. Wet.
9. By heat and smoke first.
10. Evidently amidships, as main hatches blew off.

XXII.

1. "ST. MUNGO."—Sailing ship.
2. Dundee—Point de Galle.
3. About 1,700 tons; Townhill Colliery steam coal; double-screened.
4. July, 1873.
5. 13th September, 1873.
6. Yes; nine ventilators, besides plank ventilators to all the hatches.
7. Fine, dry.
8. Very dry.
9. Smoke was seen on 13th September, and she was abandoned on 14th September.

10. Aft. under poop.

NOTE.—Coals came *fresh out of pit.*

XXIII.

1. "WALTER BAINE."—Sailing ship.
2. Dundee—Calcutta.
3. 1,170 tons; Spence's Wishaw Ell coal; single-screened.
4. 8th July, 1873.
5. 27th September, 1873.
6. Through ventilated; white pine was down the hatches and connected through along keelson.
7. Very wet.
8. Wet.
10. Main hatch.

XXIV.

1. "ISABELLA KERR."—Sailing ship.
2. Dundee—Calcutta.
3. 1,955 tons; Ell coal from Lanarkshire pits.
4. August.
5. 25th September.
6. Yes; wooden ventilators up each hatch and along keelson.
7. Wet.
8.
9. Captain found great heat coming up at the after hatch ventilator five days before smoke came up.
10. After hatch, fore and aft in 'tween decks.

NOTE.—Water stated to have got in through side lights.

XXV.

1. "ARRACAN."—Sailing ship.
2. North Shields—Bombay.
3. 1,441 tons; Cowpen coals.
4. September 10th, 1873.
5. 16th February.
6. Yes; six openings of two planks from beam to beam in between decks for the lower hold, two built ventilators in the house each end for the deck, and two hatches, one each end.
7. Fair and rain.
8. Dry.
9. Smell rising and hot in fore hold on 14th February, 1874; battened down, 16th; she fired in two days.

10. Supposed to be about fore rigging, starboard side, below the betwixt deck.

NOTE.—It is stated that the supposed cause of fire was *damp* in small coal in the hatchway.

XXVI.

1. "INDIAN EMPIRE."—Sailing ship.
2. Shields—Bombay.
3. 1,977 tons; Howard's (West Hartley) best quality steam; double-screened.
4. September 27th, 1873.
5. 11th January, 1874.
6. Yes; longitudinal shaft on each side keelson, and upshafts connected therewith coming up out of each hatchway.
7. Nothing particular as to wet.
8. Cannot say.
9. Warmth felt in ventilators on deck 3 days previously, and subsequently a yellow smoke came up shafts.
10. About 8 feet aft the quarter hatch, in lower hold.

NOTE.—Reason for fire stated—That the coals were shipped *too soon* after being dug, and not sufficiently screened.

XXVII.

1. "JOHN."—Sailing ship.
2. Porthcawl—Valparaiso.
3. 564 tons; Abbw smelting coal; unscreened.
4. September 12th, 1873.
5. 102 days.
6. Yes.
7. Very wet.
8. Wet.
9. By gas and smoke in forecastle 60 hours before the flames burst through all.
10. In after hold.

XXVIII.

1. "ANNA."—Sailing ship.
2. Cardiff—Singapore.
3. 1,420 tons; Insole's Merthyr steam coals; double-screened.
4. May 2nd, 1874.
5. 1st July, 1874.
6. Yes; with wooden pipes along the keelson and vertical ones in each hatchway (3); two others from main deck to 'tween decks; hatchway kept constantly open except during rainy or bad weather.

7. Very fine and dry.
8. Coal appeared dry, and was very dusty.

NOTE.—There was no fire, but the coal became gradually very hot; temperature on deck, 55° F.; below, 110° F. They threw overboard 300 tons.

XXIX.

1. "BRENHILDA."—Sailing ship.
2. Glasgow—Calcutta.
3. 1,776 tons.
4. 23rd June, 1874.
5. Cannot state to date exactly; on two different occasions found the coals heated, smoking, and smelling strong of gas; turned them over, and removed about 20 tons until all heat and gas subsided.
6. Yes.
7. Very fine.
8. Dry.
9.
10. Fore hatch in lower hold.

NOTE.—Attribute the heating to coals coming direct from pit.

The following letter was received by the owners from Captain Scurr:—

"GENTLEMEN,

"I beg to state that fire broke out 6th November in Calcutta in the fore hatch, where I had turned the coals over on my passage out. I applied for the steam floating engine, and the port conservator sent it alongside at once, and put six jets on board, they putting 3 feet 6 inches water in the ship: in half an hour all smoke and gas ceasing, I stopped pumping. At the time I should say I had discharged 500 tons of coal out of the main and after hatch. On getting down to the heated coals I found about 15 cwt. to a ton like a cinder, or rather resembling coke. I have carried one cargo of coals out to Bombay from Sunderland, year 1866; 1,800 tons in the ship 'Thomdean' with no ventilators, and never opened the main or after hatch, the fore hatch seldom; making a long passage of 130 days.

"In 1853 I was seaman on board the ship 'Hannah,' from London to San Francisco with coals, no ventilators, the coals being six months on board and never heated.

"JOHN SCURR."

XXX.

1. "ADMIRAL FITZROY."—Sailing ship.
2. Cardiff—Valparaiso.
3. 525 tons; Insole's No. 3, Rhondda; shipped through and through as worked.
4. July, 1874.
5. 22nd September, 1874.
6. Yes.
7. Wet.

8. Slightly wet.
9. At 2 p.m. of the 21st September a quantity of smoke was observed coming up the fore hatch, and, on examination, coals were found to be very hot, and impossible to stop below. At 4 p.m. fore hatch was battened down, the cargo being evidently on fire. At noon of the 22nd inst. an explosion took place, which blew the main decks out from fore part of main hatch to the poop, and at 1 p.m. flames were coming up through the hatch.
10. See above.

XXXI.

1. "INDUSTRY."—Sailing ship.
2. North Shields—Bombay.
3. 1,475 tons; Davison's (West Hartley) steam coal; single-screened.
4. July, 1874.
5. 19th October, 1874.
6. Yes; Ventilator fore and aft, the ship's keelson and shaft through each hatch leading into it; the fore and aft hatches were never on, and ventilation well looked after.
7. Fine.
8. Large, good and dry.
9. Gas in cabin and smoke from aft hatch two days before vessel was abandoned.
10. After hatch.

NOTE.—The coal was taken out of the pit, and *at once put on board.*

XXXII.

1. "GLEN FELT."—Sailing ship.
2. Cardiff—Chili.
3. 610 tons coal, 591 tons coke; Pen-y-craig; non-screened; smelting coal.
4. July 30th, 1874.
5. October 28th, 1874.
6. Yes.
7. Very fine.
8. Very moist.
9.
10. Between the after part of fore hatch and after part of main hatch.

XXXIII.

1. "NORTHBROOK."—Sailing ship.
2. The Tyne—Madras.

3. 1,656 tons of coal, 866 tons coke.
4. August, 1874.
5. December, 1874.
6. Yes; iron ventilators, and a free current of air through the hold.
7. Changeable.
8. Slightly damp.
9.
10. After-hold, immediately under hatch.

NOTE.—To dampness the firing is attributed.

XXXIV.

1. "NEW LAMPEDO."—Sailing ship.
2. Liverpool—Panama.
3. 1,499 tons.
4. 10th August, 1874.
5. 16th November—(ship abandoned on this date).
6. Yes.
7. Very wet.
8. Very moist.
9.
10. It was supposed that the fire originated in the main hatch, low down.

XXXV.

1. "LA ESCOCESA."—Sailing ship.
2. Cardiff—Valparaiso and Payta.
3. 1,400 tons; South Wales.
4. September, 1874.
5. Five days previous to her arrival at Payta.
6. Yes.
7. Raining heavily.
8.
9. Smouldering five days previous to the arrival; after the arrival the hatches were opened; 400 tons discharged previous to actual fire.
10. Amidships.

XXXVI.

1. "KHERSONESE."—Sailing ship.
2. Shields—Bombay.
3. 2,022 tons; Bebside (West Hartley) steam, best quality; double-screened.
4. 19th September, 1874.

5. 20th February, 1875.
6. Yes.
7. Showery.
8.
9. Fire broke out three days after commencing to discharge cargo; no previous intimation.
10. In the way of the main hatch, about half way down.

NOTE.—Coals were *fresh out of pit.*

XXXVII.

1. "FOUNDLING."—Sailing ship.
2. Birkenhead—Bombay.
3. Mixed cargo; 795 tons Westminster Brymbo coals, 306 tons Oak Pits coals, 200 tons coke.
4. 24th September, 1874.
5. 21st November, 1874.
6. Yes.
7. Wet.
8.
9. Smoke observed issuing from main ventilator on 19th Nov.; hold full of smoke, 20th Nov.; flames burst out 21st November.
10. Supposed in main hold under main hatch.

XXXVIII.

1. "LEVANT."—Sailing ship.
2. Swansea—Valparaiso.
3. 470 tons of coal; smelting; not screened.
4. September, 1874.
5. 8th January, 1875.
6. Yes.
7. Partly wet.
8.
9.
10. Seven feet before the fore side of the main hatch, and at the bottom of the vessel.

XXXIX.

1. "CITY OF RICHMOND."—Sailing ship.
2. Birkenhead—Bombay.
3. 1,638 tons; Laird's West Hartley seam; double-screened.
4. October, 1874.
5. 9th March, 1875.

6. Yes.
7. Ordinary weather for season of year.
8. Ordinary state.
9.
10. Believe about main hatch.

NOTE.—The coals were discovered to be heated when unloading at Bombay.

XL.

1. "FEDELMA."—Sailing ship.
2. Porthcawl, Wales—Valparaiso.
3. 654 tons; Aber Coal Co. (smelting coal); not screened.
4. 12th October, 1874.
5. 6th July, 1875.
6. Yes; The ship was ventilated, fore and aft, by stanchions from deck to keelson, and 1½in. boards nailed to them, thus leaving a space of 6 in. broad from top to bottom, and dividing the whole cargo in the middle.
7. Fine.
8. Dry.
9.
10. On the starboard wing, from the after part of main hatch, and extended 20 feet aft, also from ceiling 4 feet up; the coals on fire being about 4 feet deep.

NOTE.—The cargo was discovered to be heated on the ship's arrival at Chanaral. The following is what is stated:—The coals were *warm just about two feet under the surface* when we commenced to discharge, and when we got down about four feet it became *quite cool* in all parts except the starboard wing, which *got hotter the further we got down*, and the first indication was a jet of white steam, with the smell of paraffin oil which came from the stringer.

APPENDIX B.

AT Page 82, Appendix of the Commissioners' Report, the following **REPLIES** will be found in answer to the Query :—

What time usually elapses before Coal newly raised from the mine is shipped for exportation?

Messrs. A. FINNIE & SON, Kilmarnock.

"Generally shipped same day as raised, or following morning.

Messrs. HUGHES & NEPHEW, Liverpool.

"Almost all coal from N. Wales comes from some distance. Supposing 100 tons are raised from the pit during the day (as at our Cœd Talon Colliery), they are screened, loaded up, and forwarded before the evening, and arrive at Birkenhead in the course of the following day, and are sometimes shipped at once, sometimes not for days."

Mr. E. C. DOWNING, Cardiff.

"This varies exceedingly. When the demand is continuously brisk, 12 or 16 hours would be the average time from mine to ship's hold: sometimes a delay of many days occurs. In consequence of the greater regularity of business by increase of steamers, the tendency of late years has been to reduce the interval between the time of working the coal and the shipment."

Messrs. JOHN PIRIE & Co., London.

"This depends on the state of trade. When demand is good the coal is put on board with the least possible delay—often in a few hours. When trade is bad, it has sometimes to wait a market on the banks or in trucks."

Messrs. MERRAY & CUNNINGHAME (LIMITED), Glasgow.

"From two to ten days; average four to five days."

Messrs. W. S. Partridge & Co., London.

"We believe districts differ in their mode of acting on this point. At present, and for some years, very little in N. Wales has been put on the bank for shipment. The rule is to put newly-raised coal direct into waggons, and send the waggons by first train to the ship."

Mr. John Traill, Cardiff.

"When trade is regular, and the supply of shipping sufficient, much S. Wales coal is shipped in 24 hours to 36 hours after being raised."

Mr. Joseph Fothergill, Agent to the Cowpen, Hartley, & Strakers West Hartley Coal Co., Newcastle-on-Tyne.

"Five to six hours; there has been no change."

Messrs. James Smith & Co., Glasgow.

"Usually not more than 10 days; no change of late years."

Mr. Rd. Bittaby, Cardiff.

"Coal is generally sent as fast as it is raised, and is usually tipped within 24 hours."

Mr. John Macdinan, Glasgow.

"About 48 hours."

Messrs. Barnes, Guthrie, & Co., Cardiff.

"Coal is generally shipped within 24 hours after coming out of the mine."

Mr. E. M. Stamford, Cardiff.

"Coal is frequently shipped within 24 hours after it is worked from the mine."

Mr. D. Turner, Peninsular and Oriental Steam Navigation Company Liverpool.

"Since the commencement of the late strikes in the coal trades, and the consequent short delivery, I find the time elapsed between the dates of leaving the mines and that of shipment is from 24 to 48 hours."

Mr. Alexander Dalziel, Cardiff.

"From 12 hours to three or four days, according to the demand."

Messrs. John Carr & Son, Newcastle-on-Tyne.

"From 3 to 24 hours."

APPENDIX C.

EXTRACTS FROM THE STATUTORY INQUIRIES HELD BY BOARD OF TRADE, &C., GIVEN IN THE APPENDIX TO THE REPORT OF THE ROYAL COMMISSIONERS ON SPONTANEOUS COMBUSTION OF COAL IN SHIPS.

"CATTOFIELD" Barque, of Aberdeen, of 450 tons register.

Port Elizabeth, 17th September, 1868.

Inquiry into the circumstances connected with the loss of the barque "Cattofield," destroyed by fire near the island of Tristan D'Acunha, and abandoned on the 25th August, 1868.

Appeared WILLIAM ROBERTSON, who, being duly sworn, deposes:—

I was chief officer of the barque "Cattofield," bound from Leith to Penang, laden with coals. We sailed from Leith on the 22nd June last. Everything went on right *until the 24th August*, when just after dinner we observed smoke coming out of the after cabin, which I reported to the captain, who said he could hardly believe such, and that I must go and examine. I did so, and found the smoke ascending through the after hatch. I took the hatch off, and found the coals very heated. I reported such to the captain, who examined it himself. The captain held a consultation as to what was best to be done, and all were of opinion there was no immediate danger, and so we secured all the hatches and bore away for the nearest land, which was Tristan d'Acunha. By 4 or 5 o'clock that *same night the smoke increased* so much as to prevent the men going down the forecastle. We made preparations to leave the ship in the event of the fire breaking out before morning. *Early the next morning an explosion took place, blowing off the fore hatches*, previous to which the decks had become so hot as to melt the pitch. About two hours afterwards another explosion took place, blowing off the lazarette hatches. In the cabin the smoke now became so dense that we were unable to go below. The vessel was still sailing towards the island, but no land visible from the masthead. We then put some clothing in the longboat and some bread and water, ready to leave at a moment's notice. We did not try to extinguish the fire by pouring water down, because the smoke was issuing so dense that we could not reach the hatches. At 10 a.m. that morning, the 25th, we sighted a vessel and made signals of distress and steered towards her, and she bore down to us and lowered a boat and sent us assistance. We put some more clothing in that

boat, lowered our own, and some of the crew left the ship. The captain, the carpenter, myself, and one or two others remained on board our vessel; but the heat and smoke became so bad that we were compelled to abandon the vessel, and just as we were leaving another explosion took place, blowing off the main hatches, the captain being the last man to leave the ship. It was the "Glenlyon," bound to Bombay, that rendered us assistance. The carpenter scuttled the vessel before leaving her. We all went on board the "Glenlyon" and sailed her course, and on the 10th we were put on board the barque "Aletheia" off Cape St. Francis, and landed in Algoa Bay on the 13th instant. The vessel was still visible when we abandoned her, but dense smoke issuing from all parts. Our hatches were properly battened down fore and aft. I considered the fire had gained too much hold of the cargo when we first discovered it to enable us to extinguish it by pouring water on it. *The cargo seemed to be generally on fire.* The ship was not supplied with a fire engine. I was not present when the cargo was shipped. The ship had not strained at all. The object of scuttling the ship was to prevent collisions with other vessels. She was scuttled from the outside.

Cross-examined.

I first discovered the smoke issuing from the after cabin, and the fore hatch blew off first. I thought the whole cargo was on fire, and *so general* that we did not know where to commence throwing water down. No one could have worked in the hold, from the *dense heat, smoke, and sulphur that arose.* We battened the hatches down with a view of smothering the fire by preventing access of the air. I should think we were 250 miles from land. I have never heard of coal fires being extinguished. We found it impossible to remain any longer on board. We transferred some of the clothing we had placed in our longboat to that of the "Glenlyon."

WILLIAM ROBERTSON,
Chief Officer.

Before us, the 18th September, 1868,
JOHN CAMPBELL, R.M.,
F. S. READ, Assessor.

HENRY JOHN BASTARD, duly sworn, deposes:

I was second officer on board the barque "Cattofield," and remember the chief officer reporting smoke was issuing from the after cabin. I went with him to examine it, when we found smoke coming up the main and after hatchway. We took the main hatch off, examined the coals, which we found very hot, and smoke coming up the ventilators through the main hatchway. We thereupon battened the hatches down fore and aft, and steered for the island Tristan d'Acunha. About 8 o'clock that same night the crew came aft and reported the smoke to be so dense that they could not stop in the forecastle. We got the longboat ready for launching, and

put some water and provisions in it, in case the fire should break out, and be compelled to abandon the vessel. An explosion took place the following morning, blowing off the fore hatches. The decks had become very hot. Some time after another explosion took place, blowing off the lazarette hatches in the cabin. The smoke increased, but no flames issued. We sighted a sail, which bore down to us and sent us assistance. The smoke and heat had increased so much that we could remain no longer on board, and we all left the ship and went on board the other vessel, being the "Glenlyon." Before leaving our vessel the carpenter scuttled her. An explosion blew off the main hatch just as we were leaving her. On first discovering the fire we had no hopes of extinguishing it. I saw the cargo shipped. The coals were perfectly dry, the hatches were properly battened down, and the ship was tight. From what I could judge the fire seemed to be general.

HENRY JOHN BASTARD.

Before us, this 18th September, 1868,
JOHN CAMPBELL, R.M.,
F. S. READ, Assessor.

JOHN MASSON, duly sworn, deposes:

I was carpenter of the barque "Cattofield," and remembered when the vessel was first discovered on fire, on the 24th August. I examined the coals, and found them very heated; smoke was issuing from them. We battened down the hatches. The smoke increased to such an extent that the men could not remain in the forecastle. The following morning, between 5 and 6 o'clock, an explosion took place, blowing off the fore hatch. Some time after another took place, blowing off the lazarette hatches. The smoke and heat had so much increased that we could not go below. During the day we sighted a vessel, and sent us assistance on board. The smoke had become so dense and the heat so great that we could no longer remain on board, and we abandoned the vessel and went on board the other, which proved to be the "Glenlyon." Just as we were leaving the ship another explosion took place, blowing off the main hatch. After we got into the boat I scuttled the vessel by cutting a hole with an adze at midships, just above the copper line. We then sailed in the "Glenlyon." I think it was then about 3 o'clock in the afternoon. I saw the vessel about 5 o'clock. There was smoke issuing from all parts, but no flames were visible. The ship made no water; she was quite tight. I did not see the cargo shipped.

JOHN MASSON,
Carpenter.

Before us, this 18th September, 1868,
JOHN CAMPBELL, R.M.
F. S. READ, Assessor.

Statement of SAMUEL E. JANE, late master of the barque "Cattofield," of 450 tons, burnt at sea.

On the 24th June, 1868, I sailed in command of the barque "Cattofield," of Aberdeen, from Leith, laden with a cargo of coals at that port, and bound for Penang. On the following day, 25th June, anchored in Aberdeen Bay to land a sick man. At 9 p.m. of same day got under weigh and proceeded on the voyage.

Nothing of import occurred until the 24th August, when the ship had reached the latitude of 34 deg. 24′ S., longitude 15 deg. 40′ W.

About 1 p.m. on that day smoke was observed issuing from the after cabins. I immediately examined the hold, and found smoke ascending up through the coals and ventilators, and the heat very great a little below the surface. The coals had evidently ignited. I then had all the hatches closed down to prevent flame from bursting out, and bore away for the islands of Tristan d'Acunha, distant about 250 miles in S.S.E. direction.

At 9 p.m. the smoke became so dense it was impossible to remain below, the fire increasing rapidly, and smoke issuing from every aperture. Fearing it would be impossible to reach the islands, at midnight got the boats ready for launching, placing a little provisions and water in each, in order to leave the ship at any moment, should the flames break out.

At daylight on the 25th, nothing was visible from the mastheads; we continued running towards the islands, the wind blowing strong from the N.E. with a rough sea. About this time an explosion took place, blowing off the forward hatch.

About 9 a.m. a sail was descried ahead from the main top-gallant yard. I immediately steered for her with distress signals flying, and about noon we were near enough to exchange signals. She proved to be the ship "Glenlyon," of Quebec, from Liverpool, bound to Bombay, commanded by Captain McIntyre, who on learning our condition at once hove to, and sent a boat alongside to render us any assistance needed.

The wind freshening and the sea rising, no time was to be lost in leaving the burning ship, it being now utterly impossible to get below.

We then launched the boats, and, putting what clothing could be got into them, abandoned the ill-fated "Cattofield" about 3 p.m. on the 25th August last, scuttling her before doing so.

Previous to the last boat leaving the ship *another explosion* took place, blowing off the main hatches. The smoke rushed up in clouds. I immediately jumped into the boat and shoved off.

S. E. JANE,
late Master of the "Cattofield."

Port Elizabeth, 17th September, 1868.

Judgment of the Court.

The Court is of opinion that the abandonment of the barque "Cattofield."

was not caused by the wrongful act or default of the captain, but the cause of her loss was spontaneous ignition of her cargo of coals.

JOHN CAMPBELL, Resident Magistrate.
F. S. READ, Assessor.

"PERSIA," of Glasgow, a wooden ship of 1,289 tons register, four years old, classed A1 for seven years.

The Mauritius Marine Board met on Friday, 27th November, 1868, for the purpose of enquiring into the loss by fire of the ship "Persia," of the burthen of 1,289 tons, James Clark, master, which took place in lat. 40 South, long. 21 East, or thereabouts, on the 2nd. instant.

Members of the Board present:

D. WALES, Harbour Master and President.
A. W. BARCLAY, Surveyor and Merchant.
J. COWIN, Surveyor.

Appeared before the Board for examination, and were duly sworn:

James Clark, master; Peter Hutchinson, mate; Hugh Conville, 2nd mate; together with several of the crew of the late ship "Persia."

The master and the two mates were examined on oath; their evidence was clear and precise. It was not considered necessary to call in any of the crew.

It appeared from the evidence, and also from the log book, that the "Persia" sailed from Greenock on the 31st August, 1868, laden with coals and bound to Bombay; she was tight and staunch when she left, and continued so to the time of her loss. The voyage was prosecuted successfully till the 1st of November, when gas and smoke were observed rising from the coals about the midship part of the vessel, and on examination it was evident from the heated temperature that combustion was going on. This was met and combated by every available means; water was freely poured over the part that appeared most heated, the deck above being scuttled for that purpose; the force pump was worked by a portion of the crew and directed to the same spot. The water in the well soon increased to 3 feet, and the vessel's pumps were set on and the water as it rose conducted on the burning coal. Coals were dug out and thrown overboard in the hope of getting at the real seat of the fire, and a party of men remained at that work till driven on deck by the rapidly increasing volume of gas and smoke. The "Black Watch" hove in sight at this critical time; it was now evening; she laid by the "Persia" during the night, and on the morning of the 2nd November, the captain, officers, and crew abandoned the ill-fated vessel, from every hatchway of which columns of dark, black smoke, with occasional flashes of flame were issuing. Mr. Kerruish, the master of the "Black Watch," fully confirmed this part of the statement.

There was in fact so little time to spare that hardly any of the effects of the crew were brought away, and the master and mates lost everything, certificates included. There is no doubt in the opinion of the Board that every possible exertion was made to save vessel and cargo.

In reference to this loss the Board would remark that in their opinion the burning of coal-laden vessels demands the serious investigation of scientific men. These fearful accidents are increasing in frequency, and spontaneous combustion is hardly a satisfactory conclusion to arrive at. Why is there spontaneous combustion? Why does one ship burn from that cause, and dozens of others laden from the same pit, at nearly the same time, arrive safely at their destination? Is ventilation of the coal advisable or dangerous? Ought hatches to be kept on or off? Could not inflammable gases be pumped out of a ship's hold? Is there not a method of creating gases in an inexpensive manner on board ship that would smother and extinguish any amount of fire in a vessel's hold? Such measures are spoken of commonly enough, but are apparently never carried into practice. Three large coal-laden vessels, the "Pernix," "Volante," and the "Persia" have been burnt at sea, and their crews arrived in this colony during the last year. What destruction of property? What risk to life? What privation and suffering do these burnings entail? At this moment there is a valuable vessel in this port, coal-laden, which narrowly escaped the same fate as the "Persia," the coals having been smouldering many days before they could be extinguished.

The Board submit these remarks for consideration, and hope that the very important subject they refer to may be thought worthy the attention of competent persons. Certainly any one who will point out the way in which coals may be conveyed to distant ports without greater risk than the generality of cargoes will have deserved well of owners, sailors, underwriters, and last, not least, of humanity.

D. WALES, Harbour Master, President.
A. W. BARCLAY, Marine Surveyor.
JOHN COWIN, Marine Surveyor.

"L'AGOUHANNA," of Glasgow, a Quebec-built ship of 1,103 tons register.

Bombay Fort Police Court,
Tuesday, 16th February, 1869.

Pursuant to the Government notification, Marine Department, dated the 10th instant, appointing John Connon, Esquire, Acting Chief Magistrate of Police, and Lieutenant G. O'Brian, Carew, late Indian Navy, to conduct an investigation into the circumstances connected with the loss by fire of the ship "L'Agouhanna" on Tuesday, the 2nd instant, about 30 miles west of Hurnee, and 100 miles south-west of Bombay, the Court assemble this day at half-past 2 o'clock p.m. for the purpose stated.

Mr. Hearn, solicitor to Government, appears to watch the case on behalf of Government.

William Kennedy sworn; examined by Mr. Hearn.

I was captain of the ship L'Agouhanna." I hold a master's certificate from the Board of Trade, No. 28,697, dated 14 July, 1863.

She was Quebec-built and 1,103 tons burthen. We were bound from Liverpool for Bombay with a cargo of coal. The coal was shipped in Birkenhead Docks. It was called West Hartley coal or North Wales coal. It came by railway as far as I could tell direct from the pits. We came out of the docks on the 30th of September last, and started direct on the voyage. Everything went right up to the 4th of February. On the 2nd of this month my second officer, who has been acting for the chief officer, Mr. McKee, came and reported to me, about 7 o'clock in the evening, that there was a *smell of something like naphtha or coal tar*, and that the paint was a little stained just by the forehatch. I went to investigate this, but I could find no greater heat than I had noticed during the rest of the voyage. There was a little steam, but nothing more than I noticed three days after we left Liverpool. I sent the second officer down below the same evening. He reported that there was no more heat below than there was on the forehatch. Next morning, a little after 4 o'clock, when I went on deck, the boatswain came and said he thought there was fire in the ship. I sent for the carpenter, and sent him below. He came up in about ten minutes, and reported the ship was on fire, and that the smoke was coming up strong by the stanchions, and said there was every appearance of fire amongst the coal. I immediately ordered the force pump to be got out, and applied water to every available place in the hold. We continued throwing water with buckets as well as the pumps till 8 p.m. The smoke was at that time so strong that the men could not stop below for more than a few minutes at a time. The smoke was coming up through all the hatches and through the ventilators besides; of these we had one upright down each hatch. There was an upright ventilator connected with others that went fore and aft both above and below the beam. At this time we were in 30 fathoms water, and about 30 miles from the land, as far as I can judge south-west of Hurnee. The wind was about north-north-west. The ship was under sail, making the best we could for the land, and so we continued until 4 o'clock next morning, the weather being at that time very fine. At 4 o'clock on Wednesday morning, 3rd February, I called the hands aft and told them my opinion about the ship being on fire, and ordered the boats to be got ready and provisioned in order to be prepared for the worst. That was all done by daylight; water was still being thrown below by the hose. The men had been obliged to leave the forecastle at 3 o'clock. In the course of the night I tacked the ship to the westward, fearing to get too near the land; at 3 o'clock I tacked again to the eastward to get nearer the land. About 7 or 8 o'clock, as

near as I can remember, the smoke became so strong we could not stop on deck and we had to take to the boats, and about a quarter of an hour after that we saw the flames coming up through the after hatch, the cabin skylight, and the stern windows. About an hour after this, when we were pulling for the land, the main and mizzen masts fell, and between 11 and 12 the foremast fell. I reached land with my boat about 10 at night. One or two of the other boats had reached from 4 to 7. We made out the glare of the burning ship until about 12, when it disappeared.

All the crew came safe to land. I saved my chronometer, part of my clothing, and sextant. I lost all my charts and nautical books with the rest of my library.

This is the ship's third voyage to Bombay with coal. I never experienced an alarm of fire before. I noticed no particular difference between the coal on this occasion; in fact, there was less steam on this occasion from the coal than there was from the coal on the first voyage.

I can only attribute the fire to some inflammable quality in the coal, and I think the fire first took place in the bottom of the ship. According to my experience, coal is always shipped, or stated to be shipped, direct from the pits, and, according to my experience, coal ships now-a-days catch fire more frequently than they formerly used to do.

Taken on oath before us, WILLIAM KENNEDY.

JOHN CONNON,
Acting Chief Magistrate of Police.

G. O'B. CAREW,
Lieutenant, late Indian Navy.

"COMMODORE PERRY," of Newcastle, wooden vessel of 1,978 tons register, 14 years old, classed at American Lloyds A1½ for 3 years in January, 1869.

Bombay Fort Police Court,
Monday, 6th September, 1869.

Pursuant to the Government notification, Marine Department, dated the 1st instant, appointing John Connon, Esq., Senior Magistrate of Police, and Lieutenant G. O'Brien Carew, Indian Navy, to conduct an investigation into the circumstances connected with the loss by fire of the ship "Commodore Perry" in the Bombay Harbour on the night of the 28th August last, the Court assemble this day at half-past 2 o'clock, for the purpose stated.

Mr. HEARN, solicitor to Government, appears to watch the case on behalf of Government.

THOMAS BLACK sworn; examined by Mr. HEARN.

I was the master of the ship "Commodore Perry." I have received a copy of the report on which this investigation is ordered. The "Com-

modore Perry" was shiprigged, and a wooden ship 1,978 tons register; she belonged to Messrs. Thompson & Harper, of Newcastle-on-Tyne. I am not certain, but I think she was 14 years old; she was classed American Lloyds A1½ for three years in January last. I was on a voyage from Newcastle to Point de Galle for orders, with a cargo of coals. We had 2,560 tons of coal on board. It was Davidson's West Hartley coal. I saw part of the coal put on board, but not the whole. Part was shipped by wagons and about 250 tons out of lighters, from about 2nd February to 23rd March last. This is the second voyage I have taken her with coals. The coals were loaded dry. The ship had three decks. The lower hold was nearly full, the first deck two-thirds, and the next deck a little over one-third. The coal was stacked. Between the coal and the decks there was a current of air above and on the sides of the coal. Besides this the coal was ventilated by the fore and after hatches. A ventilator about four feet square ran from the poop down to the lower hold. I left Newcastle on the 8th March, and arrived at Galle on the 7th July last; but having to put out again on account of the current, I did not get back again till 23rd of the same month, and left the following day for Bombay. On the 25th August a report was made to me that there was a large quantity of steam in the fore hatchway. I could not make out what it was at first, but on Friday, the 27th, I made out that the ship was on fire. There was a great deal of smoke in the latter part of the afternoon of that day. We made Kennery Light at dusk on Saturday evening, the 28th. The pilot came on board about 9 p.m., and shortly afterwards there was an explosion, which blew the fore hatches up, killing or suffocating the steward. The ship was immediately anchored. There was no flame visible at this time. The smoke was nearly all coming out of the fore hatch. The cabin was filled with smoke. I got the boats out as speedily as possible, being afraid that the ship might blow up in the main hatchway. After I got the boats out I went on shore for assistance. I first went on board Her Majesty's overland transport "Euphrates." I gave orders to the chief officer what should be done during my absence. I got back to the ship at about a quarter-past five. She was then on Karanja shoal; she was a little below her loaded mark, tide ebbing at the time. She was burning very much forward at that time. Two water boats at that time were playing on her. They continued playing on her for the most part of that day. I went on shore about 6 o'clock to procure lighters to save the ship's stores. I went back towards the ship at half-past 5 in the afternoon, and found every one had left the ship. I returned to the shore in the Anchor bay. I gave up all idea of getting the fire under. The ship continued to burn from that time till she was consumed. I have been back to her three times. The second time I saw her she was burnt down to the level of midships, and below the loading mark at either end. I attribute the fire to spontaneous combustion of the coal. I can form no opinion why this cargo of coal

caught fire while the other did not. I should have thought the other cargo of coal was more likely to take fire, as I am generally suspicious of Welsh coals. I have had a great deal of experience of coals, and as regards this cargo it was shipped under unusually favourable circumstances. It was fine weather, and the coal was shipped very dry. I produce the certificate I hold from the Board of Trade as Master, dated 4th March, 1852, and No. 3,632. THOMAS BLACK.

Taken on oath before us,

JOHN CONNON, Senior Magistrate of Police.

G. O'B. CAREW, Lieutenant, late Indian Navy.

"BEACON LIGHT," of St. John's, New Brunswick, of 916 tons register. She was launched at New Brunswick on the 8th September, 1869, and classed in the French Lloyds for seven years.

A Marine Court of Inquiry will assemble at the Police Court, Steamer Point, to-morrow morning, the 26th instant, at 7, to investigate and report on the circumstances attendant upon the burning of the ship "Beacon Light."

President: Lieutenant PRIDEAUX, Assistant Resident.

Member: W. K. THYNE, Esq., Harbour Master, and Conservator of the Port.

Aden Residency, 25th January, 1871.

The Court having assembled pursuant to orders, proceed to read aloud a report handed in by the master of the "Beacon Light," in presence of the officers and crew of that vessel:—

Report of ship "Beacon Light," 916 tons register, of St. John's, N.B., Fry, master, from Greenock to Rangoon, coals.

September 1st. We towed from tail of bank off Greenock to Lamlash, and left there on the 2nd. We had light winds and a tedious passage to the Equator; nothing whatever occurring more than is common in any oversea voyage until November 3rd, when Gustav Stoltenhoff, O.S., fell from the cross-jack yard to the deck and was hurt, but no bones broken. On November 8th, at 5.30 p.m., smoke was seen coming up the fore hatch. Master and first mate went into the hold immediately and saw smoke coming up through the cargo at the afterpart of the deck-house on the port side, not far from wood ventilator that went down into the cargo. Immediately took off main hatches and hove coals overboard, so as to be able to get to play water. The force pump was also at once put to work and continued to play water during the night. The main hatch beams and two beams forward were cleared to our view by coals being discharged. The coals and beams on the beams on the port side from main hatch forward to some distance were hot, and it was here the smoke came from. We played great quantities of water from main and force pumps.

November 10th, 6 p.m. We had strong hopes that we were conquerors, but to our utter astonishment, about 3 a.m., on the 11th, great quantities of smoke came from the port side, not allowing any one to go into the hold. We considered it best to batten down main hatches and cut holes in the deck to admit water from main pumps with a hose. In the afternoon removed the long boat from the foreward house to after beams, some hands employed getting sails ready for boats, and others pumping.

6.30 p.m. Crew all on deck, some pumping, others in the act af getting sails and painters ready for boats.

With a loud report like a cannon, and a flash like lightning, all hatches were blown up, fore and aft, carrying the second mate overboard with main hatches, who was seen no more, as night was coming on and great quantities of smoke coming up fore and main hatches, a heavy sea running at the time. The master ordered the boats to be got out for the preservation of life, as there was no chance of saving the ship. The long boat was got out with much difficulty. In getting out the pinnace she was capsized alongside, and John Tompson, seaman, drowned. Everybody, from master to ordinary seaman, used every effort night and day to save the ship. The ship was being steered S.E. by E. in hopes of getting to Tristan d'Acunha. About 9.30 p.m., as near as we could judge, we parted from the ship. Great quantities of smoke were coming from all her hatches. We steered for Tristan, and on Sunday evening saw the land. On the following morning we were met by the kind settlers of that island who had both bread and milk with them in their boat. They joyfully welcomed us to their homes. We were in the boat three nights and two days, in all 61 hours. The boat is left for the good of the settlement on the island. Lat. 35 deg. 31′ S. long. 18 deg. 31′ W. at noon of November 11th, ship run 52 miles S.E. by E., which made us about 274 miles from Tristan when we left the ship.

We, the undersigned members of the crew, declare this to be a true and faithful report of the said ship and her loss.

Edwin Fry, Master.	William South.
George Stout, First Mate.	Jacob Goldhamer.
Albert Jackson, Steward.	F. Kramer.
William Gilchrist.	G. Stoltenhoff.
Johan Peter Engstron.	Robie South.
T. Jansen.	J. Wright.
H. P. Oalson.	J. A. Nilsen.

Ship "Northfleet," January 24th, 1871.

"BERNICE," of Liverpool, a sailing vessel of 1,455 tons register, nine years old, and classed A1 at Lloyds, which class would last until June (1873).

Bombay Fort Police Court,
Friday, 4th April, 1873.

Pursuant to the Government notification, Marine Department, published in the Government Gazette of the 3rd instant, appointing John Connon, Esquire, Senior Magistrate of Police, and J. E. Betham, Esquire, master of the ship "Princess Somerwatby," to conduct an investigation into the circumstances connected with the total loss by fire of the ship "Bernice," on Saturday, the 22nd March, 1873, in latitude 18 deg. 25′ North, longitude 72 deg. 15′ East, the court assembles this day at 11 o'clock a.m., for the purpose stated.

Mr. PEILE, officiating solicitor to Government, appears to watch the case on behalf of Government.

JAMES STANNUS sworn: examined by Mr. PEILE.

I was master of the late ship "Bernice." I have received a copy of the report on which this investigation is held. I hold a certificate of competency as master, granted by the Board of Trade in 1853, No. 9,179. The ship was registered in the port of Liverpool. Her tonnage was 1,455 and 33. She was a sailing vessel, and was built at St. John's, New Brunswick, in 1864. We sailed from Shields on the 9th October, 1872. We had coals on board weighing 1,894 tons and 15 cwt. She was classed A1 at Lloyds, which class would last until June next. I believe the ship was insured. I know nothing about the cargo. All due and possible precaution was taken with reference to ventilation. There were trunk ventilators at each hatchway, which communicated with fore and aft trunks in the lower hold. I had eight deck ventilators. I have had much experience in hot climates in carrying coals. I never saw a cargo of coals better stowed than this. The coals were dry when they were taken on board, and it was dry weather when they were so taken on board. We had very light winds and hot weather, and made slow progress. Up to the 17th March last there had been no indication of any heating or fire among the coals, and the water in the tanks which were stowed amongst the coal in the after part of the ship remained quite cool. On the 17th March the ship was in latitude 15 deg. 53′ North, longitude 72 deg. 34′ East. At 6 o'clock that morning, in consequence of what the chief officer told me, I went into the fore hold with the chief mate. I cleared away some coal; smoke and vapour were coming out just abaft the foremast. I immediately commenced pouring water over the coals. I put the hatches on, and closed the ventilators in all places to exclude the air. We kept pouring water down night and day, till the flames drove the men away from the pumps. On the 19th March, about 4 o'clock in the morning, an explosion took place, blowing the decks up from the main hatch forward. It blew all the hatches and skylights up, and also

the house forward occupied by the men. Several of the men were hurt, two rather severely. Two of the men are now in hospital, and are getting better. After the explosion a great deal of vapour was coming out of the fore part of the ship. The barque "Ocean Belle" was seen that morning, and I signalled to her to come up and remain by us. She did so till we left the ship. On the 22nd, about 6 o'clock in the morning, the flames broke out all over the ship, driving the men away from the pumps, and at 7 o'clock that morning the crew left the ship. I stopped there half-an-hour longer. The foremast had fallen before I left, and about five minutes after I left the other two masts came down. The ship was all in flames fore and aft. I and the crew went on board the "Ocean Belle." The "Ocean Belle" remained near the wreck all day. In the middle of the day I went as close to the "Bernice" as I could safely get, and saw that she was a mere shell. There was a great mass of fire and very little smoke. From the time I discovered the fire I did my best to reach Bombay, hoping to keep the fire under till then. The coals belonged to the Peninsular and Oriental Company, and their own surveyor superintended the shipping of the coals in Shields.

By the Court.

I know the ship was insured, but I do not know anything about the cargo. I do not know the amount the ship was insured for. I got instructions about the insurance of the ship. The ship was drawing 22 feet 4½ inches aft, and 22 feet 2½ inches forward. In my judgment the ship was not overloaded; she would have carried 2,000 tons easily. She had 1,894 tons on board. I had every assistance and kindness from the "Ocean Belle." The crew were under proper control. I have been three years in the "Bernice;" I have seen her deeper loaded with salt. We had five boats on board; they were all in good order and ready for use. I saved four boats and sundry other articles belonging to the ship, which have been sold by auction. I saved my nautical instruments, but lost most of my effects.

JAMES STANNUS.

Taken on oath before us,

JOHN CONNON, Senior Magistrate of Police.

J. E. BETHAM, Captain of the ship "Princess Somerwatby."

"ST. MUNGO," of Glasgow, iron ship of 1,375 tons register, eight years old, classed A1 for 21 years.

Proceedings of the Mauritius Marine Board in the case of the ship "St. Mungo," of Glasgow, of the burden of 1,375 tons, Frederick Broom, Master, which vessel was burnt in latitude 34° 57′ South, and longitude 20° 18′ West, on the 13th September last, on her voyage from Dundee to Point de Galle.

The Board assembled at the Port Office on Monday, the 20th October, 1873.

Were present:

JOHN MORGAN, Esq., Acting Harbour Master and President.

JOHN COWIN, Esq., } Marine Surveyors.
W. A. BARCLAY, Esq., }

Assisted by:

Captain J. ANDERSON, barque "Lawton Vale."

Captain W. H. METCALF, ship Beechardass Ambaidass."

Presented themselves for examination:

Frederick Broom, master; John Henry Buckler, first mate; Alexander Scott, second mate; William Ross, steward; George Wilkie, carpenter; Charles Reilly, A.B.; John Miller, A.B., of the late ship "St. Mungo."

W. H. Hathorne, master of the American barque "Taria Topan."

The following documents were laid before the Board:—

1. The official log-book.
2. The chart by which the vessel was navigated.

All evidence was on oath.

FREDERICK BROOM sworn:

Thirty years old; born at Rochester; holds a certificate of competency. Has been to sea 16 years. Has been 12 months in command of the ship "St. Mungo." Was my first command. The vessel was insured; she was built in 1865; she was classed A1 21 years. The vessel was tight, and in a proper and seaworthy condition when leaving Dundee. First symptoms of smoke were seen on the morning of the 13th September. The vessel left Dundee on the 9th July; had a full cargo; was not overladen; she had about 500 tons of coals in the 'tween decks; her draught of water was 20 feet 3 inches when we left. No symptoms of smoke or smell were discovered before the morning of the 13th September. The ship was well ventilated (nine ventilators), one ventilator went down through each hatchway down to the kelson, two on the poop went through the main deck, two through the main deck between the fore and main hatchways, two through the main and top gallant forecastle deck. After the first appearance of smoke my first order was to get all stores of a combustible nature upon deck; whilst that was being done, I went down in the hold, accompanied by one of the seamen. The steward, William Ross, was the first person who saw the smoke at 8-15 a.m., on the 13th September, issuing from the after-hatch ventilator and reported it to me. I could not stop long down the hold on account of the smell of the gas, and had great difficulty in getting on deck again. The man Robertson was with me, but he did not appear to be as much exhausted as I. When I came on deck I ordered everything to be battened down. During the time they were battening down hatches I went down the three ventilators followed by the chief officer, and found cool from kelson to about six feet up, the smell of

the gas being so strong below that no one could stand to work. No wet coals were taken on board at Dundee. Four p.m. everything appearing cool, and no smoke observable. I had one of the ventilators on the poop opened to allow the foul air, if any had generated, to escape. I allowed it to remain off for a short time and then put it on again. After this precaution I felt no fear of an explosion. At 8 p.m. the crew came aft and asked me to close on a barque which had been in company with us to windward all day, but I had already altered my course so as to keep her in signal distance. At 10 p.m. and also at midnight there appeared to be no presence of fire. At 3 a.m., the fore, main, and after hatches, blew off with a terrific roar, and a flame leaping half way up the mainmast and immediately going out, but dense volumes of smoke arising from all hatches. I immediately set all hands drawing water and pumping with both force pumps down the mainhatch, and cut holes in the deck as well, and as soon as the smoke had partly cleared, I made a line fast round me and got into the hold, but still could see no traces of flames, but conclude it was in the body of the ship. At 5-30 a.m. we sighted the barque "Taria Topan," and bore down upon her and asked him to stop by me. I also sent a boat for the captain and got him on board and showed him the exact state we were in, and agreed upon signals in case of us being compelled to obtain his assistance, intending in my own mind to try and get the ship into the Cape. The crew said that they would work with greater will if we steered so as to sight Tristan d'Acunha or the nearest land, and if the ship was then safe, they would do their utmost to get her into the Cape. This was agreed upon by myself and the captain of the barque. Every effort was made to get the fire under, but it was of no avail. At 2-30 p.m. the men said they saw no abatement; in fact, the fire was increasing, and they wanted to leave the ship, but I got them to try again with a will for one hour, and then I would see what was to be done (myself and the officers heaving coals overboard, trying, if possible, to get nearer to the fire, but we had to desist on account of the sulphur). At 3 p.m. the flames burst through the deck out of the starboard-chain-locker, quickly spreading all over. Seeing that no more could be done to save the property, and deeming it necessary for the preservation of life, I signalled the barque to close, and gave the order to get the boats out and abandon the ship, which was effected by about 6 p.m., by which time the ship was in flames fore and aft. At about 8 p.m., as could be seen, there was only the mizzen-mast standing, and it on fire. At 10-30 p.m. the boats being secured, the captain filled on his vessel, the flames could be seen up to about 12-30 a.m., the barque going at the rate of nine knots per hour.

In concluding my evidence, I cannot omit to testify to Captain W. H. Hathorne, his officers and crew, my sincere gratitude for the aid and assistance they kindly lent me on the occasion, and for the hospitable and generous manner in which we were all treated whilst on board his vessel.

"WAVERLEY," of Liverpool, of 999 tons register.

Inquiry held at Singapore, this 16th day of October, 1873, into the loss of the British ship "Waverley," of Liverpool, official No. 45,453, $999\frac{7}{10}$ tons burthen, bound from Shields to Singapore with a full cargo of coals, before the Hon. J. W. W. Birch, Police Magistrate, and Messrs. E. M. Smith and H. Ellis, Nautical Assessors.

ROBERT CALVERT, sworn, states:

I was master of the late British ship "Waverley," official No. 45,453. I left Shields on Friday, 27th June, 1873, with a full cargo of coals, bound to Singapore. We proceeded all well until the 16th September, when we sighted the island of St. Paul's. On the following day we got a *strong smell of gas*. On examining, we found neither smoke nor fire down below, but which we thought was caused by want of ventilation. On the 18th September, after removing the coals from the hatchway, we found the smoke coming up. An explosion took place. We tried to put out the fire by battening down the hatches. The hatches were *blown right off every two hours*, and we found it impossible to batten them down. About 10 p.m. on the same day an explosion took place, and blew the hatches up, and the flames reached nearly to the masthead; after which we hove to, put the boats out, and put provisions in them. On the following morning, after daylight, vast volumes of smoke issued from all hatchways, and we considered it time to leave the ship. We remained by her till she sunk the next morning, about 2 o'clock. We remained till sunset, when we were picked up by "President Van Ryckevorsel." I think the leaden pipes of the force pump got melted, and the water must have come in. On 17th of September our position was, latitude 38 deg. 23′ South and longitude 81 deg. 37′ East; on 18th, latitude 38 deg. 6′ South, and longitude 86 deg. 45′ East; and on 19th, latitude 37 deg. 39′ South, and longitude 88 deg. 7′ East. On Saturday, the day we were picked up, our position was, latitude 37 deg. 44′ South, and longitude 89 deg. 34′ East. Our cargo was West Hartley coals. I had nothing whatever but coals which could have caused an explosion. When we left the ship it was blowing a strong breeze from north-west. Everything was quite correct three weeks before, when I had occasion to trim the coals. A fire occurred in the centre compartment, and it was impossible to get down here, as the coals were choked full to the top.

R. CALVERT, Master, late ship "Waverley."

Before us,

J. W. W. BIRCH, President, Police Magistrate.
E. M. SMITH, H. ELLIS, } Nautical Assessors.

WILLIAM COLE, sworn, states:

I was mate of the late ship "Waverley." I hold a certificate of com-

petency as master, No. 5,032, from the Board of Trade. I lost my certificate in the ship. The vessel was lost. On 17th September we perceived a *slight smell of gas.* On the 18th we discovered *smoke* coming up the ventilators. On the night of the 17th all was shut up; the water in the tanks was quite cool. About 10 a.m., 18th September, an explosion took place. I never saw explosions of that sort before. We got provisions on deck, and secured the hatches. On the evening of the 18th, about ten o'clock, a heavy explosion took place, and blew the hatches off. We got the boats off, and at daylight on the 19th, at 5-30, we left the ship. The vessel went down about 2 o'clock on the morning of the 20th. I think the melting of the pipes and brass around must have caused the vessel to go down so soon. I lost my log-book. I believe the ship's papers were saved. The fire broke out in the centre compartment. It was impossible to get down there, as the coals were up to the beams. We did pour water down on the main hatch, but gave it up as useless. I never saw explosions like this before. The explosions were accompanied by a noise like a steam whistle. All hands were saved. We were to the eastward of St. Paul's about 500 miles.

WM. COLE, First Mate, late ship "Waverley."

Before us,

J. W. W. BIRCH, President, Police Magistrate.

E. M. SMITH, H. ELLIS, } Nautical Assessors.

PATRICK MIAGHA, sworn, states:

I was second mate of the "Waverley." I have a certificate from the Board of Trade, No. 93,771, which I now produce. I recollect the day the gas commenced to escape, viz., on Wednesday, 17th September. We thought it might be foul air. At 6 a.m. the next morning we discovered the fire. Smoke was seen issuing from the ventilators, which I at once reported to the captain. I received orders to go down amongst the coals. I went to all parts of the ship I could get into, but found no signs of fire. In the afternoon we set to work to get provisions on deck, in order to batten down the hatches, thereby putting out the fire. We were prevented by the explosion, which blew off the hatches. We got the boats out during the night of the 18th, and at 5-30 a.m. on the 19th we took to the boats, but hung on to the ship. The vessel was hove to before we got the boats out. She was all in a flame; the masts fell, and she went down about two hours before daylight. A few hours before she went down the boats got parted. There was a heavy sea on. We were picked up the next evening. We poured water down the main hatch, but it did no good. The ventilators were taken down, and the opening for them stopped up. At the latter part of the 18th the explosions became very frequent, and it was impossible to keep the hatches down. The explosion was something

like the noise of steam passing through the safety valves. We sounded the pumps regularly all the way. I never saw the pumps used during the time I was in her. All was done to save the ship that could be done.

PATRICK MIAGHA, Second Officer, late ship "Waverley."

Before us,

J. W. W. BIRCH, President, Police Magistrate.

E. M. SMITH, H. ELLIS, } Nautical Assessors.

"HERBERT GRAHAM," of Newport, Mon., wooden ship, of 377 tons register, six years old, classed A1, 13 years.

Town Hall, Newport, Tuesday, January 6th, 1874.

Coram:

NELSON HEWITSON, Esq., Mayor.

THOMAS BEYNON, Esq.

Assisted by

Captain H. HARRIS, W. PARKER, Engineer, Mr. DARLEY, Shipwright, } Assessors.

Mr. HAMEL appeared for the Board of Trade to conduct the case.

Inquiry as to the loss of the barque "Herbert Graham."

Mr. HAMEL opened the case.

EVAN ROBERTS, sworn, states:

I was late master of the "Herbert Graham," and held a certificate of competency as master, which certificate I lost during my travels in Patagonia. I joined the "Herbert Graham" on the 1st day of July last. She was laden, and ready to go out. We had a crew of 10, all told. We had 536 tons of coal on board, and were bound for Valparaiso. I went into the hold several times on the voyage. In fore hold there was a large space between the coals and the deck, about 7 or 8 feet; the after hold was full. I never saw the vessel empty. We had a half-poop on deck rising 3 or 4 feet; the cabin occupied the whole of the poop. We ventilated the ship by means of the after and fore hatchways. These were continually kept open except in bad weather. The hatchways were, I think, about 8 by 6. We had fine weather all the voyage except for about 12 days off the River Plate, in the beginning of September. It was windy weather, which obliged us to close our hatches; so much water was going over that we were bound to close them. No complaints were made till the 19th of September by the crew of the *gas*. On that morning at eight bells the mate told me the watch had not come on deck. I went forward and saw three men lying on the *forecastle floor unconscious*. I could not get a word out of them. They had a stove fire in the forecastle at this time; it was cold weather. I got a rope and made it fast to the three men, and pulled up one at a time

on to the deck and in about 20 minutes they came right and then they told me the forecastle was *full of sulphur*. I ordered the men to leave the forecastle, extinguish the fire, and clean it out. I sent them to a house in the break of the poop. The hatches fore and aft were open at this time. The men would not live in the house; it was too cold, they said, and they returned to the forecastle. This was the next day. I let them go. I heard no complaints. After that the forecastle was nicely cleared up, and they lighted the fire again. Nothing occurred till the 22nd of September. At 6 p.m. they reported (that is, one of the seamen did) that smoke was coming out of the fore hatch. Myself and the mate went to see what was the smoke, and we found very little, but ordered the hatches fore and aft to be battened down close; that was done, and in about an hour, more or less, they were opened again. When they were opened a second time the vessel was full of smoke, which cleared away in about 10 minutes. I went below to examine the hold, and found that the cargo of coal was on fire right amidships. I went on deck and ordered the vessel to be battened down close again, and changed the ship's course for the land. Smoke was escaping through the night from the tarpaulins on the hatchways, and the fore companion. Next morning my men were very anxious, and wanted me to put out the boats. At daylight in the morning (23rd September) we erected two big davits, one on each quarter, to support the boats. It was not safe to leave them on the hatchways. They were put into the davits ready for lowering. In the morning continually the smoke was coming out from under the tarpaulins over the hatchways, and the deck was getting hot. At 9 a.m. we sighted the land, Port Santa Cruz, bearing W.N.W., distance about 35 miles. All sail, except the two royals, were set, and we were making for the land. At about 10 a.m. it became calm; then she had no way. It was a very fine day. I consulted with the mate, and we thought the best thing to do was to open the hatchways and discharge a part of the cargo. We opened them between 11 and 12 to see if we could extinguish the fire. When we did so we found the vessel was full of smoke; we could hardly breathe in it on deck. There was a smell of timber burning in the hold. The smoke all cleared away in about 10 or 15 minutes, when the fire burst out from the fore and main hatch. The boats were at once lowered, and the men went into them, except the mate, boatswain, and myself. We remained on her poop for about an hour and a half. We were looking at the flames coming up. I went on the main deck once or twice, and the pitch was boiling out of the seams, so that I could not remain there. The men remained in the boats by the ship. We three got in at about half-past 1 or 2 o'clock of the 23rd. When we left the ship the flames were ascending 4 or 5 feet above the main hatch. I did not go on board again. We saved most part of our clothes and effects, and the log books, but we lost them, the men left them in the long boat. We did not remain. The wind came off the land in the afternoon. We pulled for the

land, and I saw her masts, fore and main, come down about 5 o'clock that afternoon. She burnt up till 3 o'clock of the morning of the 24th September, and then disappeared. The ship on the voyage was very tight, made very little water, and was pumped out morning and evening in two or three minutes. We landed on the 26th about 25 miles N.W. of Cape Virgin on the coast of Patagonia. In landing one man fell overboard into the surf from the long boat. We picked him up again, but he afterwards died from the cold and exposure. His name was John Rowley, able seaman, a native of Quebec. We buried him on the beach under a cliff; he was a healthy man. We proceeded in the boats about 54 miles by the shore, and on the morning of the 6th of October a large steamer passed us. We signalled to her; she took no notice. I could see people on the deck. I don't know whether they saw us. It was about 9 o'clock in the morning. Seeing our provisions were getting short we started overland to Sandy Point. We started nine in number till we came to a river; five of us crossed, and the other four said they would go back to the boats; they went; I waited two hours; they would not come with us. In six days we reached Sandy Point, walking most of that time. We met some natives about a mile from that place. We were very kindly treated by the Governor of that place. We had nothing but water the last three days of our journey; previously we had six biscuits each. From Wednesday till Sunday, the 12th, we had no food. We left there on the following Tuesday in one of the Royal Pacific Mail Steamboats for Valparaiso, and from there we were sent to Liverpool in another steamer. I can give no opinion as to the cause of the fire.

(*By Mr. Graham.*) We had two chronometers on board.

[The Court decided that Mr. GRAHAM had no *locus standi.*]

(*By Captain Harris.*) There never was much water in her.

(*By Mr. Darley*). We had first-class iron pumps; 9 inches of water in the well; the delivery pump about 6 inches, fitted with breaks. We had double breaks, but never fitted them, as we never had occasion to do so. We first discovered the fire under the main hatchway. I could not find the particular spot of the fire. I could not bear my hand in the coals 6 inches down on the 22nd September. We had no ventilation but the after and fore hatches. The ship was in fine trim, draught 16 aft and 15 forward.

EVAN ROBERTS.

GEORGE FARRER, sworn:

I was mate of the "Herbert Graham." I hold a certificate of competency as mate. I joined her on the 1st of July, same day as the captain, the day she left. Her cargo was in. On the Friday before we saw the smoke the men complained of gas. We had been 81 days at sea; the weather was very hot. On the 19th September saw the men lying on the

forecastle floor, and I helped to pull them up; they were all right in about 20 minutes. I saw the smoke coming from the hatches we battened down. I went with the captain to inspect; we found the cargo very hot. We dug in as far as we could with our arms; we felt it the hottest about midships, where was the bulk of the cargo. The hatches were battened down till the day after we saw the smoke. At about midday the smoke overpowered us; shortly after the flames broke out. We lowered the boat and prepared to get to land, finding we could do no good. I and three others left the captain at the river; we returned to our boats, and seeing a steamer, the "Cuzco," we pulled to her. She took us on board, waited for us about half an hour, and landed us at Liverpool. I never smelled any gas from the coal. I could not smell sulphur. In the hold the smell caught our breath. It was the smell like the burning of oak timber. During the voyage we put no water down. We did not use shovels.

(*By Mr. Darley.*) When we first saw the smoke we did not think the coal was on fire. Our vessel had about 5 feet freeboard. Our pumps were fixed in.

G. FARRER.

"MINNIE GRAHAM," of Newport (Mon.), barque of 273 tons register, five years old.

Town Hall, Newport (Mon.), Friday, March 13th, 1874.

Coram:

NELSON HEWERTSON, Esq., Mayor.
THOMAS BEYNON, Esq.

Assisted by

Captain HARRIS, and FINTON WAKE, Esq. } Nautical Assessors.

Inquiry directed by the Board of Trade as to the circumstances attending the abandonment of the "Minnie Graham."

Mr. HAMEL appeared for the Board of Trade to conduct the case.

Case opened by him, and calls—

ROBERT BALE, sworn, states:

Iiam a seaman, and shipped as boatswain acting second mate on board the "Minnie Graham." I shipped on the 16th July, and sailed the 17th from Newport. We had a crew of ten all told and a full cargo of coals. I noticed the coal was shipped wet. I saw a few trucks that was wet. It was mixed coal, large and small. We were bound for Valparaiso. We had two main pumps on board abaft the main mast. We had four small ventilators coming through the mooring post. They were cast iron and came through the covering board. I could get my arm into them. They went straight up and down, and could be plugged at the top. The plugs were out when it was fine weather, and put in when it was rough. We

had three good-sized hatches, ordinary size; they were always off on the voyage when the weather permitted. Not the main hatch, but the fore and aft ones. Always a wash of water across the main hatch; that was not so in fine weather. We never raised the main hatch in fine weather. We had a long boat shipped across the main hatch, and it was a good deal of trouble to get off. We had fine weather till we got off the Plate. She rolled easily. The wash I refer to came over the covering board. I believe the mate saved the log-book. *Three or four days* before we first saw smoke there was a *strong smell of gas* in the forecastle, and also in the cabin. Nothing happened before this. We had an average voyage. The escape of gas was reported to the captain. He came to see what was the matter. He went into the fore cabin, and also in the hold. After that the hatches which had been opened were battened down. It was cold weather at the time. We were the other side of Cape Horn at the time. We were not in sight of land. Soon after the hatches were battened down we could not stay in the forecastle for smoke. The hatches were kept on till we saw the ship that took us off. It might be four days. The ship was the "Naval Reserve." We signalled her. She put out her boats, came alongside. Our boat was taken off the hatches after she boarded her. We had two boats. The small one was got out before the "Naval Reserve" boarded us. We had not provisioned the boats. The captain and carpenter of that ship came on board. They passed a survey on the ship, and the main hatches were taken off. I dug away the coal under the main hatchway by direction of the two masters. We found the coal so hot just below the surface that I could hardly hold it in my hand. I dug down about two feet. Smoke was coming up as much as I could bear. The iron stanchions from the deck beam to the hold were hot, very hot; it was as much as I could do to hold them. The captain was down in the main hold and in the fore hold. I went into the fore hold and found the coals there just the same. I saw no fire. I poured in four or five buckets of water into the hole that I dug under the main hatch, but it would not penetrate, it stopped on the top. I did this to see if any steam would come up. Our captain, the captain of the "Naval Reserve," and the carpenter held a consultation (our mate was sick in bed), and they determined it was not safe to remain on board. We could not tell but what in any minute she might blow up. The ship was abandoned by us all. The carpenter of the "Naval Reserve" bored a hole just underneath the cabin deck to sink her. We were taken off in the "Naval Reserve" boats. I left in our own little boats; it was fine weather. I saved some of my clothes, just as much as I could scramble up. It was not safe to take a light below. It was in the evening when we left. Our long boat got stove. Our small boat was got on to the "Naval Reserve's" deck. It was fine weather, with whole sail breeze. I don't know how the wind was. She had not gone down about 10 o'clock that night. It was

about 8 when we got the boats in. The "Naval Reserve" landed us at Callao.

his
ROBERT × BALE.
mark.

GEORGE HARDY sworn, states:

I was an able seaman of the "Minnie Graham." I joined her the day before she sailed at Newport. I had been five years in a pilot boat, and this was my second foreign voyage. I lived in the forecastle. About three days before we left her (we left her on Sunday, the 26th of October), *I noticed gas and smoke in the forecastle. It smelled like paraffin upset. It got worse and worse; it drove us on deck the night before we left her. There was no heat, but the forecastle got full of smoke.* We could see it. It was reported to the captain, and he searched in the hold. He was driven back. Then we battened down the aft hatch, but the fore hatch was kept open, and the smoke escaped through it. The smoke got worse. We knew the ship was on fire; the stanchions were hot. So on Sunday we got the boats ready in the morning before the "Naval Reserve" hove in sight. We signalled to her, the ensign union down. She came to our assistance, and the captain and carpenter came on board, examined our ship, and we were called aft, and the captain of the "Naval Reserve" asked our opinion. We said we thought the ship was on fire. He said the same and we had best abandon her, as she might blow up or break out on us, and so we all left her. I saved most of my clothes; I went down into the forecastle for them. It was not quite so thick but what I could see my way to find them. We had thoughts of abandoning her before we saw the "Naval Reserve." We worked the pumps during the voyage. It took about five minutes to pump her out with one pump. The pumps were not choked. We were never more than 10 minutes at the pumps, and that was after a breeze.

GEORGE HARDY.

WILLIAM THOMPSON sworn, states:

I am an able seaman of the "Minnie Graham." I was the first to discover smoke on board. It was in the forecastle. When I got up in the morning I could hardly breathe. It was about eight bells. My head was like to split. I found gas and smoke in the forecastle. *It smelt like paraffin.* I reported this to the captain. I was at the wheel at the time. I went to the hold the second and third day after, and dug about two feet into the coals, and found plenty of gas and smoke to choke me. I came away, fearing I would be blown up altogether. We prepared to leave the vessel before we saw the "Naval Reserve." This was the third day after (Sunday morning). That day was the first day the main hatch was taken off. The captain and carpenter of the "Naval Reserve" came on

board, but I don't know what they did, as I was busy. The end of it all was we left her. We were called aft and our captain spoke to us. He asked what we thought of it. We said the ship was not in such a condition as we could remain on board of her. I was in the small boat which brought the captain and carpenter of the "Naval Reserve" to our ship, and remained in the boat. I have been 12 months at sea, foreign, having previously served five years' apprenticeship in a pilot boat.

By Captain Evans.

I made a mistake. Both captains were there when we were called aft.

WILLIAM THOMPSON.

DEPOSITION of WILLIAM ROYCE, first mate of the barque "Clevedon," holding a certificate of competency, No. 96,187, as first mate.

This is my first voyage as first mate. The coal was received in dock; the latter portion seemed to be larger coal than that first received. I did not notice any portion of the coal being wet. It appeared to me all dry, The weather was fine, and it did not rain. The vessel was trimmed in general from 2 to 4 feet from the main deck. The fore and aft hatches were taken off whenever we had fine weather. The vessel was also ventilated by three or more ventilators. When we first perceived the smell of fire it was suspected that the steward might have upset some paraffin oil, but on examination of the lazarette the can was found untouched, and showed no sign of leakage. There was one 10-gallon can on board. Over the fore hatch there was no smell, nor was the coal hot. The after hatch the same. In the cabin there was a slight smell. We had had heavy weather, and the ship had taken in some water. *Two days after the smell* the *smoke came out of the foremost ventilator.* The foremost hatch was taken up, the smoke was so great that it was battened down again; the same with the after hatch. Had no knowledge how long the coal had been in the lighters before shipment. I am of opinion that the vessel was not left too soon. The decks were blown up by the main and after hatches. From the time we first saw the smoke the boats were got ready on deck, and afterwards all hands were employed endeavouring to smother the fire with water. After going on board the "Foxhound," the vessel which saved us, I returned to the "Clevedon," at the master's wish, in order to see what I could save. I entered the vessel by the stern, but could not go further than the companion, the fire was so great. The last I saw of the "Clevedon" the main and mizen masts had gone overboard. The seat of the fire appeared to be on the port side of the main hatch—that is where I believe it originated, amongst the small coal.

In answer to question by master, witness deposed—

I believe the master did ask the steward whether he had been using

paraffin oil; I think his answer was that he had not, as some time before he found he could not use the paraffin oil, and used colza oil instead.

(Signed) WILLIAM ROYCE, First Mate.

Before me,

(Signed) J. DE VE DRUMMOND HAY,
Consul and President.

DEPOSITION of HENRY BOYES, second mate of the barque "Clevedon," holding a certificate of competency, No. 26,557, as second mate.

This is my first voyage in this ship, and my first with the master, Mr. Hughes.

When I joined a portion of the cargo was on board. I assisted in trimming a great portion of it below. It appeared to me to be dry. The large and small coal mixed. I know not the difference of steam coal and other coal at sight, but the cargo seemed to me to be all of one class. The first suspicion of fire was caused by *a strong smell*, which seemed to be of paraffin oil, and search was made. The smell was perceived in the cabin, and not in the fore part of the ship. This occurred on a Saturday, and on the Monday following we saw smoke, and first became convinced of a fire on board. The hatches were battened down, and about two or three hours afterwards blew up, the main hatch going first, and through that hatch water was bucketed down. I do not think the vessel was abandoned too soon. I can give no opinion as to the cause of the fire, and have no suspicion of any foul play. The coal extended underneath the cabin deck. I went down on Saturday, the day of the smell, and examined that part of the cargo, but perceived nothing.

The smell was first perceived by the first mate, myself, and steward on the companion; the lazarette was further aft, below the after cabin, where we had our breakfast, and where I had not smelt a smell.

(Signed) HENRY BOYES, Second Mate.

Before me,

(Signed) J. DE V. DRUMMOND HAY,
Consul and President.

APPENDIX C[1].

THE following information, derived from the Appendix to the Royal Commissioners' Report, shows what destructive force may be exerted by an explosion of gas from coal; and also exhibits the danger to be apprehended from the *leakage* of fire-damp from the coal bunkers into other parts of the vessel:—

(*From Page 59 Appendix, Roy. Com. Report.*)

EXTRACT FROM "WESTERN MAIL" OF THE 20TH OF JUNE, 1876.

Terrible explosion at Penarth. A ship shattered. Four seamen killed and many injured. Marvellous escape of a rigger.

The most disastrous explosion that ever occurred on board a ship at Cardiff took place at 9 o'clock on Monday morning. The inhabitants of Penarth and the Bute Docks were thrown into the utmost consternation at the intense force and report made by the explosion. So great was the shock that many believed an earthquake had shaken the foundations of their dwellings. Persons, however, about the dock at Penarth and on Cardiff pier-head observed the flames and smoke issuing from on board a large ship lying in Penarth Dock, to the height of at least 200 feet, and on hastening to the scene found that a frightful explosion, caused by an accumulation of gas from the cargo of coal, had taken place on board the barque "Atalanta," of Greenock. The decks were blown up fore and aft from stem to stern, the rigging, sails, and spars broken and enveloped in a black and dense smoke. Immediate efforts were made to get on shore the injured members of the crew.

The "Atalanta," being outward bound and ready for sea, had most of her crew on board.

She completed loading on Friday last, having shipped 1,600 tons of the Glamorgan Coal Company's large steam coal.

The ship was so much damaged that fears were felt lest any of the crew could survive the accident, but the exploring party nobly pursued their labours, descending into the ship's hold, cabins, and forecastle, in search of the dead and dying. Men were found shockingly burnt about the head, arms, and body. These were speedily landed, and placed in the store of Mr. Clode, butcher, who kindly lent his premises on Penarth Wharf for

the use of the wounded. Dr. Nell was soon in attendance, and ordered some of the cases to be removed without delay to the "Hamadryad," hospital ship. Three cases, however, he retained, viz., that of Matteo, an Austrian seaman, Donald McKerrel, the carpenter, and Captain William Brown. The Austrian succumbed to the injuries he had received at 10-30 a.m., his body being removed to the Penarth mortuary. The carpenter was subsequently forwarded to the hospital ship very badly hurt, and Captain Brown, who also was much burnt about the arms and head, was conveyed to a private residence at Penarth.

While the wounded were being thus attended to, and that in a most efficient manner, by Dr. Nell, it was discovered that Mr. Whitworth, chief officer of the "Atalanta," had been killed; also an ordinary seaman, named John Hamett. Both bodies were carried to the mortuary.

At a short distance from Mr. Clode's store another crowd was assembled around one of the dock lodges, wherein was found the mate of another ship, the "Killochan," of Greenock, most dangerously wounded. He was in the act of shaking hands with Mr. Whitworth, of the "Atalanta," on that ship's deck when the explosion occurred. Mr. Whitworth was killed, and Mr. Alexander Muir, mate of the "Killochan," was thrown about 40 feet into the air. In alighting, his head came in contact with a spar, contusing the skull. His right leg was at the same time broken. He lies, as stated, in a hopeless condition.

As to the cause of this direful event, it has been clearly ascertained to have arisen from the accumulated gas from the cargo being ignited by a match lit by one of the seamen, named Antonio Pedro. He accompanied H. Ross, second officer of the "Atalanta," into the after hold. Mr. Ross carried a naked candle, and no sooner had Pedro struck the match to light the candle, than the explosion took place. Both of these men, who are badly burnt, are lying at the hospital ship.

The "Atalanta" is a ship of 1,116 tons register; built at Richmond, United States, in the year 1857. She is the property of Mr. C. S. Caird, of Greenock, and was bound from Cardiff to Hong Kong. Strange to state, the ship that was alongside of the "Atalanta" at the time, viz., the "Killochan," likewise belonged to Greenock.

EXPLOSIONS FROM LEAKAGE OF FIRE DAMP FROM COAL BUNKERS.
(*Page* 59, *Appendix Royal Commissioners' Report.*)

"LOUISA THERESA," of Vannes, France, a wooden ship of 200 tons register, 20 years old, and classed 3/3-1-1, French Veritas.

Sailed from Cardiff for Mataro with a cargo of coals on the 16th January, 1876, and on the same date, when in the Penarth Roads, an explosion of gas took place on board, owing, it is believed, by the gas coming up

through the hatch in the lazarette and igniting by the fire in the master's cabin.

(*Page* 49, *Appendix Royal Commissioners' Report.*)

THE "BERWICK."

Greenwich Police Court, 26th September, 1873.

Inquiry into the circumstances attending the casualty on board the screw steamship "Berwick," on the 9th of May, 1873, while on a voyage from Shields to London; made by direction of the Board of Trade by Daniel Maude, Esquire, stipendiary magistrate, assisted by Admiral Powell and Mr. Darley, acting as Assessors.

THE REPORT.

The "Berwick" was an iron screw steam ship, built at Cartsdyke, in the county of Renfrew, in November, 1855. She had two decks, three masts; was schooner rigged, of 365 tons register, and the joint property of Messrs. George Elliot and David Johnessohn, of Usworth Colliery, in the county of Durham, colliery owners.

The "Berwick" was one of a fleet of steam ships solely employed in conveying coal cargoes, and made on an average from 45 to 50 voyages a year from the port of Shields to London and elsewhere.

She left Shields for London on the 8th of May last under the command of Mr. Robert Brown, who holds a certificate of competency as only mate, dated the 4th of July, 1868. She had a cargo of 732 tons of gas coal on board. On the following morning (the 9th) at 4 o'clock the Dudgeon light was passed; at 5 a.m. a thick fog set in and the engines were eased to half speed. At 6 a.m. an explosion took place in the forecastle, and one of the stokers, John Morrison, who was at the time coming up the forecastle ladder, was blown some 14 feet into the air and killed, and two other firemen who were in the forecastle were much injured.

From the evidence it appeared that the "Berwick" was 183 feet long, and divided into six compartments by five bulkheads. In the first and fourth of these compartments iron 'tween decks were laid and the lower parts were used for water ballast. The first compartment, which was immediately under the forecastle, was used for water ballast only, the second compartment was used as a store room, the third for cargo, the fourth was a ballast tank and used also for cargo, and the fifth for cargo only. On this voyage the forward tank was empty, as was usual when the ship was laden; from this tank a discharge pipe led to the bilge under the after cargo hold; the cock of this pipe was, when the tank was empty, always left open. There was also a sounding pipe to this tank, which terminated in the forecastle about 3 feet from the deck, and by the side of the hatch; this was an open pipe. There was also a rivet hole left open in the deck-flat to allow

water to pass from the deck into the tank. The Court thus traced a direct communication between the bilge through the tank into the forecastle, where the explosion took place. It appeared in evidence that the coal shipped emitted a gas, although inoderous and not detrimental to life, and was highly explosive when brought in contact with flame.

Although the evidence is not entirely conclusive on this point, the Court have every reason to believe that the man Morrison, either by a lighted pipe or match, ignited the gas that came up from the sounding pipe, thus blowing him up through the hatchway and causing a lesser injury to the other two men who were at the further side of the forecastle.

The Court, after a careful consideration, exonerated the master of all blame, and returned to him his certificate.

It appeared by the evidence that an explosion took place in the forward store room of the "Berwick" in 1867, and there is every reason to believe that it arose from the ignition of similar gases; no one was then injured, and the damage done was trifling. The owners, however, very properly ordered the Davy lamp to be used in future in the holds and store room.

The Court would suggest that the following precautions should be taken in vessels carrying coal cargoes, viz.:—

That the discharge pipes from the water ballast tanks should not terminate in the compartments where explosive gas is likely to collect, and that all sounding pipes should be carried to the upper deck.

Also that arrangements should be made by pipes or other means to ventilate the lower part of the holds of vessels where gas is likely to accumulate.

The Court also attach the utmost importance to excluding fire damp or gas from the compartments where the crew live. This requires not only great care on the part of those who survey the ship, but the constant supervision of the master.

D. MAUDE, Stipendiary Magistrate.

We concur in this report,

R. ASHMORE POWELL, WM. DARLEY, } Assessors.

(*Page 41, Appendix Royal Commissioners' Report.*)

"THE ZENO."

Board of Trade Inquiry into the total loss of the "Zeno," held at the Police Court, Borough of Kingston-upon-Hull, 11th June, 1873.

Before WALTER WRANGHAM, Esq., Police Magistrate.
CAPTAIN WHITE, R.N.
WILLIAM DARLEY, Esq., Naval Architect.

OFFICIAL REPORT OF THE INQUIRY.

The "Zeno" was a screw steamer, built of iron, and was of the follow-

ing dimensions, viz.: length, 272 feet; breadth, 32 feet; depth, 16 and 18 broken; gross tonnage, 1,490 tons; horse power, 200, with two surface-condensing combined inverted engines; draught of water forward, 15·7; ditto aft, 18·7; freeboard, 4 feet. She was the property of Messrs. Wilson, Sons, and Co., of Hull. Her estimated value was £33,000. She was insured for £11,000. She was built in 1871 by Messrs. Earle and Co.'s Shipbuilding Company, Hull, and classed 18 years Liverpool. She was brig-rigged, and manned with 29 hands all told. Was commanded by Captain Edward Owen, who holds a certificate of competency. She was divided into four compartments for hold, and the bulkheads, with one exception, were of iron and watertight, and fitted with suitable sluice valves, and arrangements for pumping from each compartment. The ship was well found in every respect. She commenced loading on Wednesday, the 7th of May, in the dock at Cardiff, the cargo taken in being 1,500 tons fresh wrought Cardiff hard brittle coal from the pits, all being loaded in 50 hours. The shippers were Messrs. Cory Brothers & Co. Her loading was completed about 1 o'clock on Saturday morning, the 10th May. She left the dock the same day (Saturday) at 5 p.m., weather foggy. The hatches were closed as follows: No. 2 on Saturday night, Nos. 1 and 4 on Sunday, and No. 3 on Monday. They were not battened down till out at sea. There were fires used in the forecastle, and lights as usual. On Sunday afternoon the carpenter went into the fore peak with a naked light (the same lamp subsequently used when the explosion took place). On Monday forenoon, the day before the accident, the boatswain went into the fore-peak with a naked light. In consequence of the dense fog that prevailed. the "Zeno" lay in the Penarth Roads until Sunday morning, the 11th May, between 3 and 4 o'clock, when she got under weigh, and proceeded slowly, the fog continuing until the afternoon of Monday, when it cleared away. On the same evening (Monday) the captain gave orders that the hatches should be removed for ventilation on the following morning, which was partly carried out. All went well until the following morning (Tuesday), about 9 o'clock, in latitude 46° 45′ N. and long. 8° 11′ W., when one of the seamen, Arthur Bennington, requiring some waste, was directed by John Andean, the lamp trimmer, to the fore peak for some. Bennington took a common spirit lamp (a naked light), and removed the wooden hatch leading to the fore peak. He placed the lamp on the deck, close to the hole, and got down, standing on some gear, in which position as he stood his head was above the deck. He had to stoop to get below the deck, and, taking the lamp in his hand, as soon as he got it below the deck, an explosion took place, bursting the platform below him and precipitating Bennington into the lower part of the bow, a distance of 14 or 15 feet. He was much burnt, and rendered for some short time insensible. The fore water-tight bulkhead which divided the forehold from the forepeak was blown into the forehold, the deck above disturbed three or four inches,

and the pillar to beam carried away. The butts of the plates of the bottom were separated from the stem on each side for a distance of 6 or 7 feet below the water, being open about 1¼ inch. Some of the butt straps were ripped from the port bow, and the plate started, and a great many rivets drawn out. The explosion found vent through the fore hatchway, blowing up five iron hatches in its passage, which in their flight broke the derrick boom into two pieces, and shivered the mast, also tearing the foretopsail and forestaysail. The casualty arose from gas being generated in the lower part of the coal in the forehold, which found its way through some small aperture in the fore bulkhead into the fore peak, where a natural receptacle was formed for it, the greater part of which must have accumulated in much less than 24 hours, and the explosion of which was due to the dangerous use of the naked light used by Bennington. Captain Owen was on the bridge at the time of the accident, and immediately ordered the removal of the remainder of the hatches. A sail was got over to endeavour to cover the aperture in the port bow, but failed for want of weights. Plugs were made and driven into the rivet holes, until the men were driven out by the water gaining on them. The captain, seeing danger, ordered three boats to be swung out at the davits to within four feet of the water. A signal of distress was hoisted, which was answered by the "Cairo" and "Brighton." Finding the openings on the sides of the stem and on the port bow were so large, it was thought advisable to keep the sluice valves closed, and the steam pumps being used without effect, steam was blown off. On all hopes of saving the vessel being abandoned, the whole took to the boats about 40 minutes from the time of the accident (the captain being the last to leave), and were picked up by the "Cairo," outward-bound, afterwards transferred to the "Brighton," the weather at the time being fine and clear. From the time of the accident to the "Zeno" going down head foremost in deep water in the Bay of Biscay was about 50 minutes. The Court, upon weighing the whole of the evidence produced, and aided by the scientific information of Mons. Vassard, have come to the following judgment:—That no blame whatever attached itself to the owners, Messrs. Wilson, Sons, & Company. From the very high reputation of Messrs. Earle's Shipbuilding Company, they have the utmost confidence in the substantial construction of the "Zeno," and of her general efficiency. They exonerate Edward Owen, the master, and return him his certificate, the usual notice on shipment of dangerous Cardiff coal not having been given to him. With regard to Joseph Whalley Taylor, the chief mate, they consider he neglected his duty in not informing the captain of the dangerous condition of the coal, after having been informed thereof by the agent at Cardiff. His certificate is therefore suspended for three months from the 11th of June. The Court feel bound, however, to point out to the Board of Trade the very dangerous properties of the Cardiff steam hard brittle coal, such as shipped in the "Zeno," as shown

by the scientific evidence of M. Vassard, with the view of stringent instructions being given to prevent vessels going to sea without some efficient ventilation. Various means were suggested, amongst which were the following: —A comprehensive system of ventilation from the upper deck by pipes, cowls, &c., as described in drawing accompanying, observing that had the "Zeno" been fitted with a cowl and ventilating pipe to the forepeak, this accident would not have occurred. The use of iron masts, uptakes to funnels of steamers, bilts, &c. By dividing the coal fore and aft by planks placed Venetian way, with a space between them, against the pillars of the hold. Also the funnel of the galley fire being utilised by means of pipes leading to it from the various parts of the hold. That each hatchway be arranged so as to admit of cowls being fitted to allow of ventilation when the weather prevents the hatches being taken off. It may be remarked here from evidence that it is more important with Cardiff hard brittle coal to have ventilation than to keep out water.

WALTER WRANGHAM, Stipendiary Magistrate.

Police Court, Hull, July 9, 1873.

We approve of this report,

E. A. WHITE, Captain R.N.
WM. DARLEY, Naval Architect.

(Page 55 Appendix Royal Commissioners' Report.)

"MIRANDA."

OFFICIAL INQUIRY held at the Town Hall, Cardiff, on the 13th September, 1875, before R. O. Jones, Esq., Stipendiary Magistrate for the Borough of Cardiff, assisted by Captain Castle and Captain Pryce as Nautical Assessors, respecting a casualty which happened on board the steamship "Miranda" off the coast of Cornwall, on the 26th August, 1875.

REPORT OF THE COURT.

The "Miranda" was an iron screw steamer belonging to Hull, official number 60,140. She was built at Stockton-on-Tees in 1868, her registered tonnage 865·73 tons, and she was owned by E. Leetham and others, at Hull.

She left Newport about noon on the 25th August with a full cargo of 1,579 tons of smokeless steam coals, bound to Kiel, and had a crew of 23 hands, all told, including the master, Mr. Wilhelm S. A. Van Deurs, who holds a certificate of competency as master, No. 18,491.

After clearing the Newport River she met with strong south-westerly winds and a considerable sea, which caused her to ship some water, but not sufficient to necessitate the hatches being put on.

All proceeded well until about 6-30 p.m., when, as the wind was increasing and night coming on, the whole of the hatches were put on and

battened down that time, until after daylight the following morning. The wind continued fresh, with a high sea, and the vessel shipped such large quantities of water that the look-out man on the forecastle had to be removed to the bridge.

After 6 a.m. the weather moderated, but the sea still continued so high that it prevented the hatches being taken off, without the risk of wetting the cargo. Nothing further of importance occurred until shortly after 12 p.m. The forenoon watch had just been relieved, and the first officer and the master were on the bridge, when about 12-15 a terrible explosion took place in the forepart of the vessel, which was instantly enveloped in smoke and flame. The engines were at once stopped, and boats got ready for lowering; meanwhile it was noticed that the whole of the forepart of the vessel, from the foremast forward, had been blown up by the explosion. As some fire was seen, the donkey engine with hose was at once set to work, and in about twenty minutes the fire was extinguished.

The extent of damage is described as follows :—

Nine beams broken.

Forecastle deck and all the butts blown to pieces.

Main-deck blown up as far aft as the foremast.

Iron bulkhead to main-hold bent aft some four or five inches.

Stringer plates on both sides lifted.

Main-rail split, and sheer-strake, and bulwarks much disturbed.

The well was sounded, but the vessel made no water.

On mustering the crew, it was found that Benjamin Davies, one of the crew, was missing, and is supposed to have been blown overboard, as portions of his clothing were found in the rigging.

The captain was most seriously burnt, and Thomas James, seaman, was also hurt. These two men were landed at St. Ives to receive medical help, about two hours after the accident, and were left in the infirmary there.

The "Miranda" then bore up for Cardiff.

The Court, on the evidence given before them, attached no blame whatever to the master, and they therefore returned him his certificate.

They find that this casualty is clearly to be attributed to an explosion of gas, caused by the use of a naked light near the scuttle of the forepeak by the carpenter, previous to and when he opened the scuttle, the gas having found its way from the hold through the collision bulkhead.

The gas had accumulated in the forehold from the time the hatches were battened down on the evening of the 25th until the explosion took place, and had no means of exit.

It was stated in evidence that the whole of the cargo consisted of freshly wrought coal, none, with perhaps the exception of a few waggons, having been above ground more than twenty-four hours. In this state it was more dangerous than it would have been if exposed longer to the atmosphere.

After loading was completed on the evening of the 24th August, the hatches were left off all that night until 6-30 p.m. on Wednesday evening, when they were battened down. From that time till the explosion, a period of 17 hours, the gas had been accumulating in the holds, which had no ventilation whatever.

After hearing competent and experienced mining engineers, and other experts on the subject, the Court feel it their duty to offer some suggestions for future guidance with regard to these dangerous cargoes, and therefore respectfully ask the attention of the Board of Trade to the following points :—

1. That all vessels about to carry cargoes of gaseous coal should be fitted with ventilating pipes or shafts at each end of either compartment or hold; that is, that there should be two ventilators in each hold or compartment, so fitted as to be constantly kept open.

2. That it is advisable in carrying this description of coal to have a small space between the deck and cargo, so as to ensure a free circulation of air between the ventilators.

3. That the Master should be instructed to have the hatches off whenever practicable during the voyage.

4. That naked lights be strictly prohibited.

Dated this 15th day of September, 1875.

(Signed) R. O. JONES, Stipendiary Magistrate.

We concur in the above report,

(Signed) JOHN. S. CASTLE, CHAS. E. PRYCE, } Nautical Assessors.

APPENDIX C².

THE TIME THAT HAS ELAPSED FROM THE LOADING OF COAL VESSELS UNTIL **EXPLOSION** HAS TAKEN PLACE.

THE following cases I have abstracted from a return ordered to be printed by the House of Commons, 14th August, 1878 (No. 366), "Coal Cargoes" (Spontaneous Combustion, &c.).

It will be observed that in one instance 13 days is recorded as having elapsed before explosion occurred. Many cases, however, have occurred of explosion in dock.

"NUEVO JULIANA," of Spain.—Sailing from Cardiff. Explosion took place the day after loading in dock. 14th June, 1876.

"LUFRA," of West Hartlepool.—Sailing from Cardiff. Explosion took place 3 days after loading. 19th June, 1876.

"GOSFORTH," of London.—Sailing from Newport. Explosion took place 13 days after loading. 15th November, 1876.

"ROSA MARY," of Hartlepool.—Sailing from Newport. Explosion took place 4 days after loading. 25th January, 1877.

"VESTA," of Shoreham.—Sailing from Cardiff. Explosion took place 8 days after loading. 15th March, 1877.

"LEVANT," of Liverpool.—Sailnig from Cardiff. Explosion took place 3 days after loading. 28th April, 1877.

"YORK," of Hull.—Sailing from Cardiff. Explosion took place 3 days after loading. 8th May, 1877.

"CHUB," of Liverpool.—Sailing from Birkenhead. Explosion took place 5 days after loading. 27th June, 1877.

"ANN WEBSTER," of London.—Sailing from Cardiff. Explosion took place 7 days after loading. 30th August, 1877.

"TRISTRAM," of France.—Sailing from Cardiff. Explosion took place 5 days after loading. 27th September, 1877.

"AMELIA," of Holland.—Sailing from Swansea. Explosion took place in dock 2 days after loading. 14th October, 1877.

"MARIE ALBERT," of France.—Sailing from Newport. Explosion took place 4 days after loading. 25th February, 1878.

"ESK," of Whitby.—Sailing from Newport. Explosion took place 4 days after loading. 11th March, 1878.

"BEN LOMOND," of North Shields.—Sailing from Cardiff. Explosion took place 2 days after loading. 7th April, 1878.

"BIAFRA," of Teignmouth, sailing from Neath. Explosion took place 2 days after loading. 1st June, 1878.

"CHRYSOLITE," of Liverpool.—Sailing from Newport. Explosion took place in dock the day after loading. 6th June, 1878.

"PERRIGNE," of France.—Sailing from St. Nazaire. Explosion took place day after loading. 22nd June, 1878.

"CADUCEUS," of London.—Sailing from Cardiff. Explosion took place same day. 28th June, 1878.

APPENDIX D.

THE TABLES AND INFORMATION ARE FROM A "MEMORANDUM RELATING TO SPONTANEOUS COMBUSTION OF COAL, AND EXPLOSIONS OF COAL GAS, ON BOARD SHIP, &C," BY THOMAS GRAY, ESQ., ASSISTANT-SECRETARY TO THE MARINE DEPARTMENT OF THE BOARD OF TRADE.

CASES OF SPONTANEOUS COMBUSTION IN BRITISH-OWNED VESSELS.*

[No. 1.]

Year.	Coal Shipped.	Price per Ton for Export.	Number of Cases.			Proportion of Cases to each 250,000 tons of Coal carried.		
			Steam.	Sailing.	Total.	Steam.	Sailing.	Total.
1871	23,511,278	9·80	...	5	5	...	·053	·053
1872	23,354,352	15·83	...	8	8	..	·086	·086
1873	23,115,001	20·90	...	14	14	...	·151	·151
1874	23,536,429	17·21	...	25	25	...	·266	·266
1875	24,674,871	13·28	...	15	15	...	·152	·152
1876	26,677,483	10·93	1	18	19	·009	·169	·178
1877	25,830,050	10·17	1	13	14	·009	·126	·135
1878	26,046,673	9·46	3	6	9	·029	·058	·087
1879	27,773,999	8·77	3	3	6	·027	·027	·054
1880	29,650,695	8·95	1	9	10	·008	·076	·084

* For remarks on this Table, see page 34.

EXPLOSIONS OF GAS IN COAL CARGOES, IN LONG & SHORT VOYAGES, IN BRITISH-OWNED VESSELS.*

[No. 2.]

Year.	Coal Shipped.	Price per Ton for Export.	Number of Cases.			Proportion of Cases to each 250,000 tons of Coal carried.		
			Steam.	Sailing.	Total.	Steam.	Sailing.	Total.
1871	23,511,278	9·80	2	3	5	·021	·032	·053
1872	23,354,352	15·83	2	1	3	·021	·011	·032
1873	23,115,001	20·90	7	2	9	·076	·021	·097
1874	23,536,429	17·21	2	2	4	·021	·021	·042
1875	24,674,871	13·28	4	...	4	·041	...	·041
1876	26,677,483	10·93	5	4	9	·047	·037	·084
1877	25,830,050	10·17	7	3	10	·068	·029	·097
1878	26,046,673	9·46	10	3	13	·096	·029	·125
1879	27,773,999	8·77	4	3	7	·036	·027	·063
1880	29,650,695	8·95	4	3	7	·034	·025	·059

* For remarks on this Table, see page 34.

TABLES 3 AND 4 WERE PREPARED BY MR. BULLOCK, OF THE BOARD OF TRADE, AND ARE GIVEN IN MR. GRAY'S MEMORANDUM.

TABLE SHOWING THE TOTAL NUMBER OF KNOWN CASES OF SPONTANEOUS COMBUSTION OCCURRING IN BRITISH-OWNED VESSELS.

[No. 3.]

Year.	Total Loss.	Partial Loss.	Total.
1871	2	3	5
1872	5	4	9
1873	12	3	15
1874	16	13	29
1875	6	12	18
1876	11	12	23
1877	7	10	17
1878	4	9	13
1879	...	9	9
1880	5	9	14

CASES OF EXPLOSION REPORTED IN BRITISH-OWNED VESSELS, DURING TEN YEARS.

[No. 4.]

Year.	In Sailing Vessels.	In Steam Vessels.	Total.
1871	3	2	5
1872	1	2	3
1873	2	7	9
1874	2	2	4
1875	...	4	4
1876	4	6	10
1877	3	8	11
1878	3	11	14
1879	3	4	7
1880	3	7	10

TABLE FROM MR. GRAY'S MEMORANDUM.

NUMBER OF COAL-LADEN VESSELS WHICH WERE REPORTED MISSING DURING THE ELEVEN YEARS ENDING DECEMBER 31st, 1880.

[No. 5.]

Year.	STEAM.			SAILING.			TOTAL.		
	No. of Vessels.	Tonnage.	No. of Lives Lost.	No. of Vessels.	Tonnage.	No. of Lives Lost.	No. of Vessels.	Tonnage.	No. of Lives Lost.
1870	1	261	18	17	6,261	192	18	6,522	210
1871	...	...	...	15	7,994	219	15	7,994	219
1872	1	1,050	26	33	13,855	361	34	14,905	387
1873	4	2,862	93	32	10,910	323	36	13,772	416
1874	5	2,827	103	46	18,295	536	51	21,122	639
1875	3	1,337	52	26	5,158	186	29	6,495	238
1876	3	2,553	70	27	10,198	286	30	12,751	356
1877	4	2,357	68	24	6,913	219	28	9,270	287
1878	3	1,420	49	14	8,395	186	17	9,815	235
1879	5	5,286	118	25	7,489	214	30	12,775	332
1880	4	3,462	86	26	8,201	225	30	11,663	311
	33	23,415	683	285	103,669	2,947	318	127,084	3,630

TABLE FROM MR. GRAY'S MEMORANDUM SHOWING THE NUMBER OF COAL-LADEN VESSELS WHICH WERE REPORTED AS MISSING DURING TEN YEARS ENDING 31ST DECEMBER, 1880, DISTINGUISHING THE VESSELS WHICH SAILED ON SHORT VOYAGES FROM THOSE WHICH SAILED ON LONG VOYAGES,* AND ALSO DISTINGUISHING STEAM-SHIPS FROM SAILING SHIPS.

[No. 6.]

Year.	SAILING.			STEAM.			TOTAL.		
	Long Voyage.	Short Voyage.	Total.	Long Voyage.	Short Voyage.	Total.	Long Voyage.	Short Voyage.	Grand Total.
1871	7	8	15	...	...	...	7	8	15
1872	11	22	33	...	1	1	11	23	34
1873	7	25	32	2	2	4	9	27	36
1874	17	29	46	1	4	5	18	33	51
1875	3	23	26	...	3	3	3	26	29
1876	8	19	27	1	2	3	9	21	30
1877	6	18	24	1	3	4	7	21	28
1878	5	9	14	...	3	3	5	12	17
1879	5	20	25	1	4	5	6	24	30
1880	7	19	26	1	3	4	8	22	30
	76	192	268	7	25	32	83	217	300

* Following the classification adopted by the Royal Commission, "Long Voyages" are held to include all vessels except those bound to European or Mediterranean ports.

APPENDIX E.

THE FOLLOWING TABLES, PREPARED BY ME FROM THE YEARLY PARLIAMENTARY RETURNS, SHOW THE AMOUNTS OF COAL, CINDERS, AND PATENT FUEL WHICH HAVE BEEN EXPORTED FROM THIS COUNTRY; AND ALSO THE AMOUNTS COASTED FROM ONE PORT TO ANOTHER IN THE UNITED KINGDOM.

AMOUNT OF COAL EXPORTED AND COASTED.

[No. 7.]

Year.	Total Quantity Exported (Tons).	Total Declared Value.	Average Price per Ton (fraction of £1).	Total Quantity Coasted (Tons).	Total Quantity Exported and Coasted (Tons).
1876	15,690,402	£8,473,851	·54	10,987,081	26,677,483
1877	14,880,899	£7,477,699	·5025	10,949,151	25,830,050
1878	14,988,527	£7,010,036	·467	11,048,146	26,046,673
1879	15,740,082	£6,793,932	·431	12,033,917	27,773,999
1880	17,891,181	£7,837,314	·438	11,759,514	29,650,695

AMOUNT OF CINDERS EXPORTED AND COASTED.

[No. 8.]

Year.	Total Quantity Exported (Tons).	Total Declared Value.	Average Price per Ton (fraction of £1.)	Total Quantity Coasted (Tons).	Total Quantity Exported and Coasted (Tons)
1876	326,707	£265,874	·8137	12,612	339,319
1877	333,640	£252,474	·7567	16,353	349,993
1878	274,239	£201,239	·7355	9,951	248,190
1879	345,438	£231,671	·6706	11,536	356,974
1880	442,797	£338,259	·7639	59,280	502,077

AMOUNT OF "PATENT FUEL" EXPORTED AND COASTED.

[No. 9.]

Year.	Total Quantity Exported (Tons).	Total Declared Value.	Average Price per Ton (fraction of £1.	Total Quantity Coasted (Tons).	Total Quantity Exported and Coasted (Tons).
1876	281,968	£164,738	·5842	15,485	297,453
1877.	205,511	£114,313	·5562	13,607	219,118
1878	221,867	£118,730	·535	15,078	236,945
1879	356,776	£181,196	·5078	15,730	372,496
1880	385,993	£197,360	·5113	16,643	402,636

COAL (PRICE OF.)

Return to an Order of the Honourable The House of Commons, dated 5th May, 1881.

RETURN "SHOWING THE ANNUAL AVERAGE PRICE (EXCLUSIVE OF CITY OR OTHER DUES) OF THE BEST COALS AT THE SHIP'S SIDE IN THE PORT OF LONDON, AT PER CHALDRON, FROM 1820 TO 1832, AND AT PER TON, FROM 1832 TO 1880."

[No. 10.]

Year.	Per Chaldron.		Year.	Per Ton.		Year.	Per Ton.		Year.	Per Ton.	
	s.	*d.*		*s.*	*d.*		*s.*	*d.*		*s.*	*d.*
1820	32	5	1832	20	10	1849	16	7	1866	19	...
1821	33	2	1833	17	2	1850	16	...	1867	19	8
1822	32	6	1834	19	5	1851	15	...	1868	17	7
1823	35	9	1835	20	10	1852	15	5	1869	17	8
1824	34	6	1836	21	10	1853	20	1	1870	17	5
1825	33	10	1837	22	11	1554	22	8	1871	18	2
1826	30	2	1838	23	5	1855	20	10	1872	23	10
1827	31	4	1839	22	7	1856	17	10	1873	31	3
1828	31	...	1840	22	6	1857	17	7	1874	24	8
1829	27	11	1841	21	3	1858	17	4	1875	22	9
1830	29	2	1842	20	1	1859	17	3	1876	20	2
1831	26	4	1843	19	1	1860	19	...	1877	18	5
			1844	21	9	1861	18	5	1878	16	10
			1845	18	1	1862	16	6	1879	16	11
			1846	16	10	1863	17	1	1880	14	11
			1847	19	9	1864	19	...			
			1848	17	1	1865	19	1			

Coal Market Registrar's Office,
Coal Exchange, 5th May, 1881.

J. B. SCOTT,
Deputy Clerk and Registrar of Coal Market.

NOTE.—A most elaborate and valuable Collection of Statistics, of every description, connected with the Coal Fields of this country, has been published this year, in 1 volume. The Work is by RICHARD MEADE, ESQ., Assistant-Keeper of Mining Records. The publishers are Messrs. CROSBY, LOCKWOOD & Co., London.

APPENDIX F.

LOSS OF H.M.S. "DOTEREL."

THE following is taken from "THE ENGINEER," of June 3rd, 1881, where also sketches are given showing the internal arrangements of the ship and a plan of the upper deck :—

"It has been announced by the Admiralty that an inquiry into the cause of the destruction of Her Majesty's ship 'Doterel' at Sandy Point, on the 26th of April, would take place as soon as possible after the landing of the survivors of her crew in this country. The inquiry will, however, not take place for some weeks until a report on the divers' operations has been received. Commander Evans has addressed his report to the Admiralty from the 'Britannia,' at Bordeaux, on the 26th inst., and this report was made public on Monday morning. After expressing his regrets, he goes on :—

"'We left Elizabeth Island shortly after 6 a.m. on the 26th of April, steaming sixty revolutions with the starboard wing boiler, and anchored at Sandy Point about 8-30 a.m., in eight and a half fathoms of water. When I had finished with the engines, I sent for Mr. Ord, the engineer—the chief engineer being in arrest—and told him that I had finished with the engines, to go on condensing and prepare for coaling. I then remained on deck a short time talking to the coal contractor and captain of the port. About 9 a.m. I went below to breakfast, and at about 9-30, when I had finished my breakfast, I again sent for Mr. Ord and told him to send some one to overhaul the steam-cutter's engine, and to be sure that there was no delay about coaling. I then sent for the senior lieutenant and told him to go to divisions when ready, as I was going to wash and dress. I then went into my after-cabin, and while in my bath heard a report as if a gun had gone off. I immediately went into the fore-cabin, the starboard side, and, on looking forward, saw that the ship's side was burst open in the starboard gangway, and that the upper deck in that part was forced up, twisted, and wrenched about, and the water rushing in, the ship at once heeling over to starboard. A short time after the first explosion—about 20 or 30 seconds, as far as I can judge—there was another and much more violent explosion, shaking the ship heavily, and which I am convinced was

the explosion of the fore magazine. Everything now became darkened with smoke and *débris*, and I felt that the ship was sinking rapidly. On turning round I saw the sentry getting out of my embrasure port. I then told my steward, who was close to me, to jump out. I then got out myself, jumped into the water, and caught hold of some wreckage. I think I must have been sucked down by the ship, as I do not recollect anything more until I noticed that the ship had disappeared, the water covered with wreckage, and a few men clinging to it, and boats coming to our rescue. I do not think it could have been more than three minutes from the first explosion until the ship sank. The explosion was so sudden and destructive that it was quite impossible to lower any boats, even had there been anyone to do so. The few men that escaped were abaft the mainmast, and saved themselves by jumping overboard. I fancy the greater number must have been killed by the explosion and falling *débris*, as I did not hear a cry or groan. As regards the first explosion, which occurred in the starboard gangway, I think it may have been caused by the bursting of the boiler. As, before we could condense good water, it was necessary to brine the boiler well on account of the mineral oil used in the cylinders, the ship having surface condensers, it is possible that the water may have been allowed to get too low in the boiler, the crowns of the furnaces exposed, and on cold water being pumped in the boiler burst. If this was not the case, I think it possible the coals in the starboard bunker may have become heated and generated gas, or have caused spontaneous combustion. If neither of these circumstances occurred, I am then at a loss to account for the first explosion, as there are no combustibles stowed in the starboard gangway, and there is little or no doubt that the shell room, Nordenfelt, Gatling, and gun-cotton magazines, all of which were abaft the mainmast, did not explode. As regards the fore magazine, it had been open the previous day, shortly before noon, two cases of charges for the seven-pounder being taken out for short practice, and the magazine closed. It was opened again at about 4 p.m. by the gunner, who returned the two cases and closed the magazine, and I must say he was a most careful and trustworthy officer. I do not think it possible that any fire could have existed below without an immediate alarm being given, as the cooks of the messes had been on the lower deck for the last twenty minutes clearing up the deck for inspection. The arms had been returned, and we were about to go to divisions. The fore magazine is on the port side, forward, a little abaft the foremast, and the damage done by the explosion was in the starboard gangway, a little before the mainmast. I do not think it possible that the first explosion could have emanated from the magazine. I left Lieutenant Stokes at Sandy Point in charge of the wreck, and to bury any bodies that might come to the surface, and also to employ a diver who happened to be there about a wreck, and, if possible, to obtain a clue to the disaster, and to remain until he received further instructions.

"'Three bodies were discovered and buried on the day of the disaster, namely, Blackmore, chief boatswain's mate; Nicholls, able seaman; and Hayes, ordinary seaman. Owing to the suddenness of this disaster, no records of the ship were saved. Every kindness and attention was shown to us by the authorities and inhabitants of Sandy Point. I regret that I am not able to give a more satisfactory and definite explanation of this disaster, which to me is a mystery.'"

The following is also extracted from "THE ENGINEER" of September 9th, 1881:—

"On Saturday, the court-martial on Commander Evans sat for the last time, and concluded the inquiry which has been carried out on board the 'Royal Adelaide,' at Devonport. Nominally appointed to try Commander Evans, the real function of the Court was to take evidence and pronounce an opinion as to the cause of the explosions on board the 'Doterel.' Vice-Admiral Hood, the president, and his colleagues have not kept the world long in suspense. As soon as Commander Evans' defence had been heard the cabin was cleared, and when the Court re-assembled a short time afterwards, the Deputy-Judge Advocate read its finding as follows: 'The Court, having weighed and considered the whole of the evidence laid before it, do find that her Majesty's ship 'Doterel' was destroyed while at anchor at Sandy Point, in the Straits of Magellan, about 10 a.m. on the 26th of April, 1881, and is of opinion that this destruction was caused by two distinct explosions which took place on board her—the first being an explosion of gas evolved from the coal stowed in the bunkers, and the second an explosion of the powder stowed in the fore magazine. There is no direct evidence to show in which of the bunkers the first of these explosions originated, nor what was the actual cause of the ignition of the gas; but the Court is of opinion that as the ship was about to complete with coal, a light may have been introduced into one of the bunkers for the purpose of examination of the bunker, and that an explosion of gas ensued which was instantaneously communicated to the other bunkers. The Court is further of opinion that the second explosion was a result of the first, and that the violence of the first explosion burst open the foremost bulkhead of the athwartship bunker, and that the inflamed gas passed direct into the interior of the magazine, either through ruptures made in the after bulkhead of the magazine, or through the copper pipe of the flooding arrangements for the magazine. This pipe was in the compartment immediately between the bunker and the after bulkhead of the magazine, and if it were broken a direct passage would at once be opened through this pipe into the interior of the magazine; and the Court is of opinion that the powder stored in the magazine was in this manner exploded. The Court further finds that no

blame is attributable to Commander Richard Evans and the surviving officers and crew of her Majesty's ship 'Doterel' for her destruction, and, therefore, fully acquits them of all blame in respect to it. And the said Commander Evans and the surviving officers and crew are hereby fully acquitted accordingly.'"

SINCE the loss of the "Doterel" another disastrous explosion has taken place, on board H.M.S. "Triumph." The following account of it is taken from "THE STANDARD," January 14th, 1882:—

"EXPLOSION ON BOARD H.M.S. 'TRIUMPH.'

"The Secretary of the Admiralty informs us that a despatch was received yesterday from Rear Admiral Stirling, Commander-in-Chief on the Pacific Station, reporting an explosion of xerotine siccative on board his flag ship the 'Triumph,' which caused the death of William N. Foxon, able seaman; Thomas H. Davies, gunner, R.M.A.; Charles Legg, gunner, R.M.A.; and wounded the following, viz.: Fredk. G. Pavett, private, R.M.L.I.; John Smith, painter; Alfred Kite, stoker (all three of whom are progressing satisfactorily); George Tribe, assistant sick berth attendant; Thomas Butler, ordinary seaman; Jack G. Sturt, able seaman; and James Williamson, able seaman (who are slightly wounded).

"The Press Association has received from an officer on board her Majesty's ship 'Triumph,' now in the Pacific, a communication stating that a serious explosion occurred on board that vessel when off Coquimbo, on the coast of Chili, on Tuesday, November 22. The writer, who has escaped uninjured, gives the following account of the disaster:—

"'We have had a terrible explosion of xerotine siccative on board here. It occurred on Tuesday last, at 8 o'clock in the morning.' The letter bears date 27th November, so that it was written five days after the accident. 'Two men,' the writer states, 'were killed on the spot, and a third died on the afternoon of the following Saturday, while many were terribly burnt. The material which exploded was stowed under the paint room, directly contrary to the Admiralty instructions. It appears that a marine went there with a light, and he was literally blown to pieces. The beds in the 'sick bay' outside the paint room were wrenched out of the deck, and the men were thrown all over it. As I have said, one man was blown all to pieces, and the second who was killed was 35 yards off, his death resulting from concussion of the brain. The man who died yesterday (Saturday) afternoon sustained frightful injuries; his thighs and abdomen were

almost blown away, and he was a terrible sight. Strange to say, the painter, who was actually inside the paint room, was only badly burnt. There is at the time I am writing only one dangerous case among the injured, that of a stoker, who is suffering from severe internal injuries and concussion of the spine. At the time of the explosion I was walking up and down on deck, and the band was playing 'God save the Queen' to the colours. It give us all a terrible fright. The exploded material had got into the double-bottom, and it was only yesterday that anyone could get near it, owing to the gas which emanated from it.'"

"The substance which thus has been the cause of a serious accident is commonly known as 'patent driers,' which are used in ironclads to prevent corrosion between the double bottoms.

"The 'Triumph' is an iron steamship of 6,640 tons, carrying engines of 4,890 horse-power, with an armament of 14 guns. Her captain is Captain Albert H. Markham."

AFTER the explosion of the xerotine siccative on board the "Triumph," a committee was appointed by the Admiralty, to inquire into the whole question in its relation to the loss of the "Doterel," as xerotine siccative was known to have been among the stores on board. From the following notice which appeared in most of the leading London newspapers of November 28th, 1881, it would appear that no satisfactory conclusions were arrived at.

"THE 'DOTEREL' EXPLOSION.

"The report of the Xerotine Siccative Committee which sat at Portsmouth, and was unable to come to any definite conclusion in reference to this explosive, has now been referred to Admiral Luard's Committee on Gas Explosives. Directions have been given to institute experiments to ascertain the explosive power of siccative under various conditions, and to report whether the gas evolved from it would, if brought into contact with a light, have had sufficient force, by igniting the powder in the magazine of the 'Doterel,' to have caused the explosion by which that ship was lost. The xerotine siccative in that case was, in error apparently, placed in the mast-hole, close to the magazine. It is said, too, that it was classed as 'paint,' and not as an explosive."

It is impossible with only the information as yet accessible to those outside the Admiralty, to give a definite opinion regarding the direct cause of the "Doterel" disaster. I would, however, again call attention here to Colonel Majendie's thoroughly practical and able report of the explosion on

board the canal boat "Tilbury," and to his experiments which I have already given.* To say the least of it, it is highly suggestive of the *probable* action which might have occasioned the loss of the "Doterel."

The conditions which Colonel Majendie found to have existed on board the "Tilbury" prior to the explosion were—the presence of 5 tons of gunpowder in the hold, also 4 barrels of benzoline—next, that the cabin in the after part of the boat communicated with the hold by means of a "small ventilating hole"—and lastly, the presence of a fire and light in that cabin.

The benzoline (which is similar to xerotine siccative) which escaped from the barrels by leakage, when mixed with the air, formed an explosive and inflammable gas. This inflammable mixture making its way through the small opening into the cabin, came in contact with the open light there, when an explosion took place, and flame was conveyed back again to its source in the hold where the gunpowder was likewise placed, resulting in the terrible explosion of the gunpowder.

As in the "Doterel," so also in the "Tilbury," there were *two* explosions.† The first or preliminary explosion, which was slight, occurring when the benzoline atmosphere came in contact with the light in the cabin—and after an interval of time, described by the various witnesses, as being from a few seconds to one minute or a minute and a half—the great explosion took place.

Colonel Majendie fixes the time at something under one minute, and with regard to this offers the following most practical remarks :—

"With regard to the exact interval of time which elapsed between the outbreak of flame on board the 'Tilbury' and the great explosion, it is difficult to arrive at any very positive conclusion. I have found, in the course of my inquiries into accidents by explosion, that no reliance whatever can be placed upon the estimates formed by different observers as to the duration or extent of particular intervals of time in immediate connection with the main event. The power of measuring time within a certain interval of an explosion seems, if one may so say, to come within the scope of the destructive effects of the explosion itself, and to be annihilated thereby. The result is that some very striking discrepancies of statement on this point on the part of witnesses otherwise thoroughly reliable have come under my notice."

In dealing with the extent and nature of the destructive effects which resulted from the explosion on board the "Tilbury," Colonel Majendie makes the following observations :—

"All that can be attempted in this report is to assign roughly the areas within which particular classes of effects were generally observable, or,

*Page 40.

† The similarity in both cases, as to the period of time which elapsed between the preliminary and final explosions, is noticeable. Commander Evans, in his Report of the "Doterel" disaster, states—"About 20 or 30 seconds," &c.

rather, the areas beyond which those classes of effects were very rarely observable.

"And these areas may, I consider, be fairly set down as follows :—

		More roughly the figures may be taken at of a mile.
Area of scorching effects, or "range of flash"...	50 yards	$\frac{1}{32}$nd
Area of serious structural damage	200 ,,	$\frac{1}{8}$th
Area of structural damage	400 ,,	$\frac{1}{4}$th
Area of damage to window frames, sashes, ceilings, and doors	600 ,,	$\frac{1}{3}$rd
Area of broken windows...	From $\frac{3}{4}$ mile to 1 mile.	1 mile
Area within which the sound of explosion was sensible	15 miles	15 miles

"Serious and extensive as is the amount of loss, injury, and inconvenience indicated by the above figures, especially when it is considered that the various areas are closely built over and thickly populated, it is impossible to doubt that it is much less than could reasonably have been anticipated had it been known that five tons of gunpowder was going to be exploded in the middle of London. If any doubt existed on this point, it would at once be removed by a comparison of the effects produced on this occasion by five tons, and the damage wrought by the explosion by Fenians of a single barrel (100lbs.) of gunpowder at the Clerkenwell House of Detention on the 13th December, 1867. On that occasion four or five persons were killed, over 40 were injured, a large number of houses (in Corporation Lane) were so shaken that they had to be pulled down, a considerable length of the prison wall, 25 feet high, and, in thickness, tapering from 2 feet 3 inches to 14 inches, was blown down, and injury done to a large number of houses throughout the district."

If the information is correct that in the "Doterel" "the xerotine siccative was, in error apparently, placed in the mast-hole, *close to the magazine*," I cannot see that the inferences can be of a very complicated nature.

I would also observe that the force or violence of the first explosion, where the vapour from the benzoline or xerotine siccative fired, would be determined by the amount of these substances vapourised and the quantity of air mixed with them. The explosion might in the first instance be slight, as on board the "Tilbury," where a man was only nearly blown out of the cabin hatch—or it might be with great violence, as on board the "Triumph," where one marine was literally blown to pieces in its immediate vicinity, and another man killed 35 yards off.

To ascertain now whether on board the "Doterel" the preliminary explosion which resulted in conveying flame to the gunpowder magazine

was occasioned by the volitalization of the benzoline, or some such hydrocarbon contained in xerotine siccative, or from the escape from the coal bunkers of fire damp mixed with air, does not appear to me to be of the consequence that apparently is attached to the *mere solving* of this problem. If these inquiries result in alone banishing xerotine siccative as dangerous, the lessons to be learned from these disasters will indeed have been entirely misapprehended.

Xerotine siccative must only be regarded as but the representative of a *class* of similar substances. All those substances which are readily volatilizable, and which when mixed with air form *explosive and inflammable* mixtures are alike dangerous,* requiring only similar conditions to produce with *any of them*, similar results. These substances may certainly vary in the force developed by their own explosion, and in the temperatures required for their volatilization and ignition, but these are differences of degree, not of kind. The greatest danger to be apprehended from them all, is not the force they can exert by their own explosion merely, but the flame they may convey to vital parts of the ship or cargo.

I would most emphatically direct attention to the fact, that such conditions *exist now* in ships of the navy and in merchant vessels, which are liable to contribute similar disasters, and that were xerotine siccative alone banished from every ship afloat, and no other precautionary measures taken, these conditions would *continue to exist.*

These conditions are :—

First—The carrying without the precautions I have stated, (of substances similar to xerotine siccative, viz.,) benzoline, naphtha, turpentine, petroleum, &c. ;

Second—The presence of open lights ;

And Lastly—The vicinity of explosives, such as gunpowder, gun-cotton, &c.

*See Appendix C 1.

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